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ATTACHED ALGAE NANTICOKE GS - 1981

Report No 83-317-K

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ABSTRACT

The influence of industrialization on the attached algal populations in the Nanticoke area of Lake Erie was investigated by comparing the species composition, abundance and metal concentration in the algae in the industrialized areas with control areas. The industrial complex consists of a coal-fired generating station (Nanticoke GS), an oil refinery (Texaco) and a steel refinery (Stelco). *Cladophora glomerata* was the dominant species at all sampling locations. The earliest growth of algae was observed in the discharge of the Nanticoke Generating Station, the only sampling location with ice-free conditions over the winter months. Concentrations of arsenic, aluminum, cobalt, zinc, phosphorus, iron, silicon, nickel, vanadium, mercury and chromium were higher in the algae near the generating station and Stelco than in the controls. Copper concentrations in the algae from the generating station were higher than in the controls. The controls had the highest levels of boron.

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EXECUTIVE SUMMARY

ATTACHED ALGAE NANTICOKE GS - 1981

M.K. Kirby

This study is one of a series in which the effects of industrial development on the attached algae in the Nanticoke area of Lake Erie were examined. The industries in the area include the Nanticoke generating station (a coal fired generating station), Texaco (an oil refinery), and Stelco (a steel refinery). When the investigation was initiated in 1967 attention was focussed on determining the effects due to the environmental modifications resulting from construction and operation of Nanticoke GS. These include the creation of a sheltered bay (the discharge channel), the installation of armour stone along the shoreline near the station for erosion protection and the discharge of a heated effluent. Pre-operational surveys of the species composition, distribution and abundance of attached algae were conducted from 1967 to 1973 at the generating station and along 12 km of adjacent shoreline. Post-operational surveys were conducted from 1974 to 1978 and in 1981. In 1981 the study was expanded to include the determination of the concentration of metals, which could potentially be emitted by Ontario Hydro or Stelco, in the algae.

The species composition of the algae in 1981 was generally similar to that observed in the previous post-operational studies. *Cladophora glomerata* was the dominant species at all locations, but was proportionately less abundant at the generating station than along the lakeshore. Conversely, the Zygnematales (*Zygnema, Spirogyra and Mougeotia*) were proportionately more abundant at the generating station than along the lakeshore. This difference in species composition is attributable to the sheltered conditions within the discharge which may be less suitable for *Cladophora* than the exposed lakeshore. *C. glomerata* grows well only in areas with considerable water movement (Neil, 1975). At the same time, the protected nature of the discharge may be more suitable for the Zygnematales which can form rhizoidal branches and become weakly attached to the substrate. A trend in species composition not previously

observed was a high percentage of *Oedogonium* along the lakeshore in 1981, but the significance of the observation is unknown.

The algae began growing earlier in the year at the generating station sampling locations than at most shoreline sampling locations. This is consistent with previous observations and is attributable to the ice free conditions existing in the discharge over the winter months. The biomass at the lakeshore sampling locations was lower in June and July than at the generating station, largely as a result of severe storms which detached the algal filaments at the lakeshore but not at the generating station. The algae at the lakeshore subsequently grew quickly, however, reaching biomass levels similar to those at the generating station in September and October.

The algae from both Stelco and the generating station generally contained higher concentrations of arsenic, aluminum, cobalt, zinc, phosphorus, iron, silicon, nickel, vanadium, mercury and chromium than the controls. Copper concentrations in the algae from the generating station were higher than in the controls and the algae from the Stelco sampling location. The controls had the highest levels of boron.

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To Mr. D.K. Gillies
Thermal Generation
Nanticoke Environmental Committee

ATTACHED ALGAE NANTICOKE GS - 1981

M. K. Kirby

INTRODUCTION

The Nanticoke Environmental Committee, consisting of representatives of the Ontario Ministry of the Environment, the Ontario Ministry of Natural Resources, Ontario Hydro, Stelco and Texaco, was established to investigate the influence of industrialization on the local aquatic environment in the Nanticoke area of Lake Erie. One objective of the Committee was to determine whether construction and operation of the Nanticoke GS would affect the attached and epiphytic algal populations of the area. As used in this report, the term attached algae is applied to filamentous species firmly attached to the substrate and to filamentous species intertwined in the mat of firmly attached species. Epiphytic algae refers to those algal species which grow on the surface of the filamentous species. Major design features of Nanticoke GS which could affect the attached algal populations were identified as the creation of a sheltered bay (the discharge channel), the installation of armour stone along the shoreline for erosion protection and the discharge of a heated effluent. The characteristics of the algal populations initially selected for regular monitoring were the species composition, distribution and abundance. Monitoring began in 1967 at the generating station and along 12 km of adjacent shoreline. It continued to 1978 and was repeated in 1981. This report contains the results of the 1981 survey. Results of the previous surveys were summarized by Kirby and Dunford (1981).

This report also contains the results of analyzing the algae for chlorophyll 'a' concentration. This was measured for the first time on a regular basis in 1981 and was included to substantiate visual observations that there were differences in the vigour of the algae at the lakeshore and generating station locations (Ontario Hydro Research Division Report No 78-238-K).

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In addition, since both Stelco and Ontario Hydro are potential emitters of metals, regular sampling of the attached algae for metal analysis was incorporated into the 1981 program. *Cladophora glomerata*, the most common attached algal species in the Nanticoke area, is considered a good biological monitor of trace metal contaminants since it accumulates trace metal contaminants up to 1000 times that of surrounding water (Keeney et al 1976, Whitton 1970, Bjerkelund and Ongley 1980). It may also play an important role in metal cycling since it forms part of the diet of invertebrates such as amphipods and crayfish, which, in turn, are consumed by fish (Ontario Hydro Research Division draft report).

METHODS

1. Species Composition and Biomass

Attached algal samples were collected for determination of species composition and biomass from six shoreline locations considered to be outside the influence of the power plant (L_1-L_4, L_7-L_8, Table 1, Figure 1) and at three generating station locations in the immediate vicinity of the thermal discharge (GS_4, GS_5 and GS_7, Table 1, Figure 2). Triplicate samples of algae were scraped from 25 cm^2 areas of rock in the splash zone each month from April to October and preserved in 5% formalin. The species of attached algae were identified using an inverted microscope and their percentage abundance was visually assessed. Any epiphytic algae present were also identified. Nomenclature follows Prescott (1962).

Dry weight was determined for all samples following 24 h of drying at 105°C. Ash free dry weights were measured following ignition of the dried samples at 525°C for 2 h in a muffle furnace. The ash free dry weights were expressed in g/m^2 and used as estimates of biomass. Ash free dry weights are considered more acceptable than dry weights as estimates of biomass since inorganic sediment can be a major portion of the dry weights (Vollenweider 1974).

2. Chlorophyll 'a'

Attached algal samples were collected from two generating station locations (GS_4 and GS_5) and three shoreline locations (L_1, L_4 and L_8) for analysis of corrected chlorophyll 'a'. Corrected chlorophyll 'a' refers to that portion of the total chlorophyll 'a' which is attributable to living cells. The remaining portion of the total chorophyll 'a' refers to phaeophytins which are the degraded chlorophyll pigments in dead cells (Ministry of the Environment 1981). Triplicate samples, weighing approximately 1 g each, were collected from each

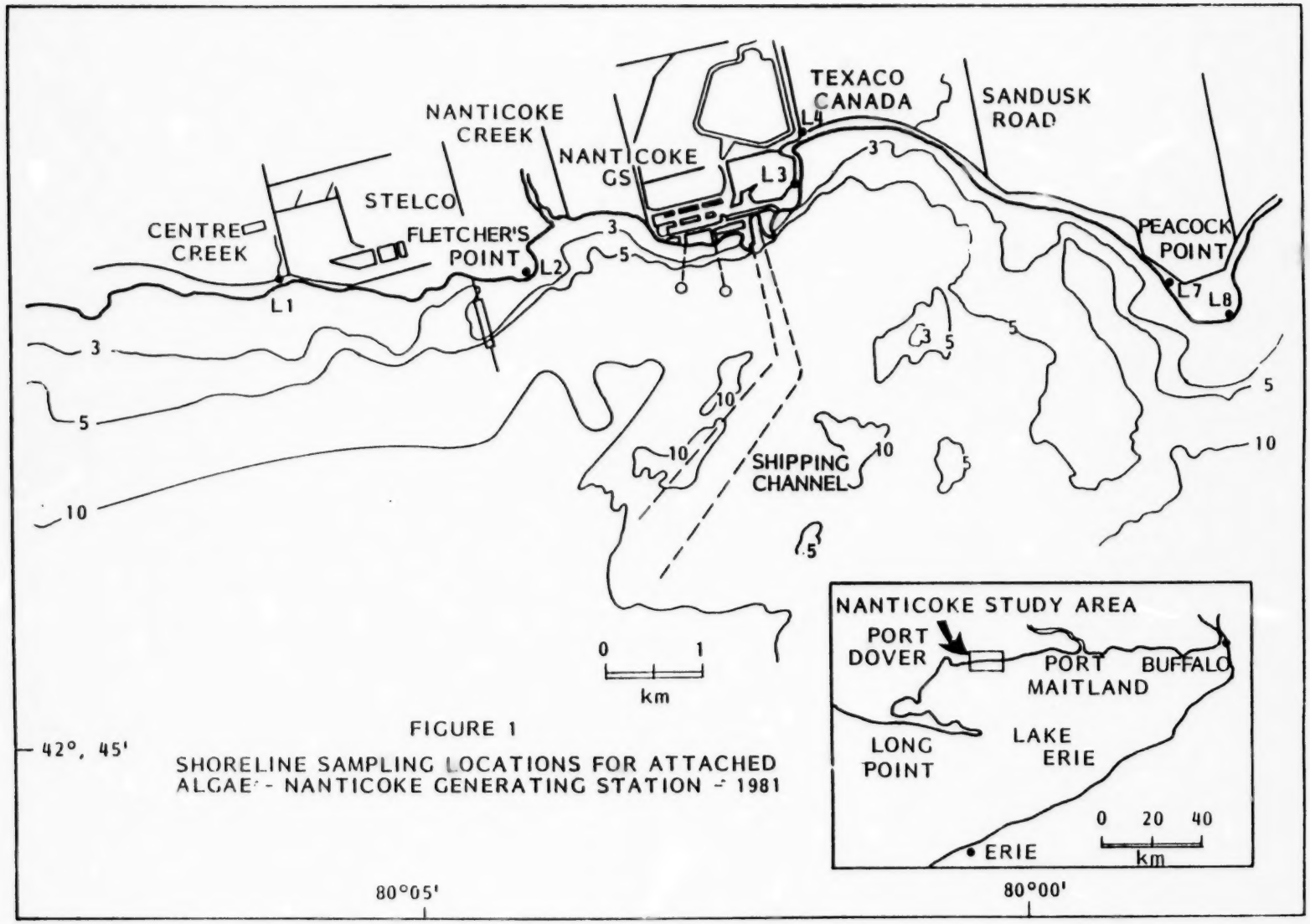


FIGURE 1

SHORELINE SAMPLING LOCATIONS FOR ATTACHED ALGAE - NANTICOKE GENERATING STATION - 1981

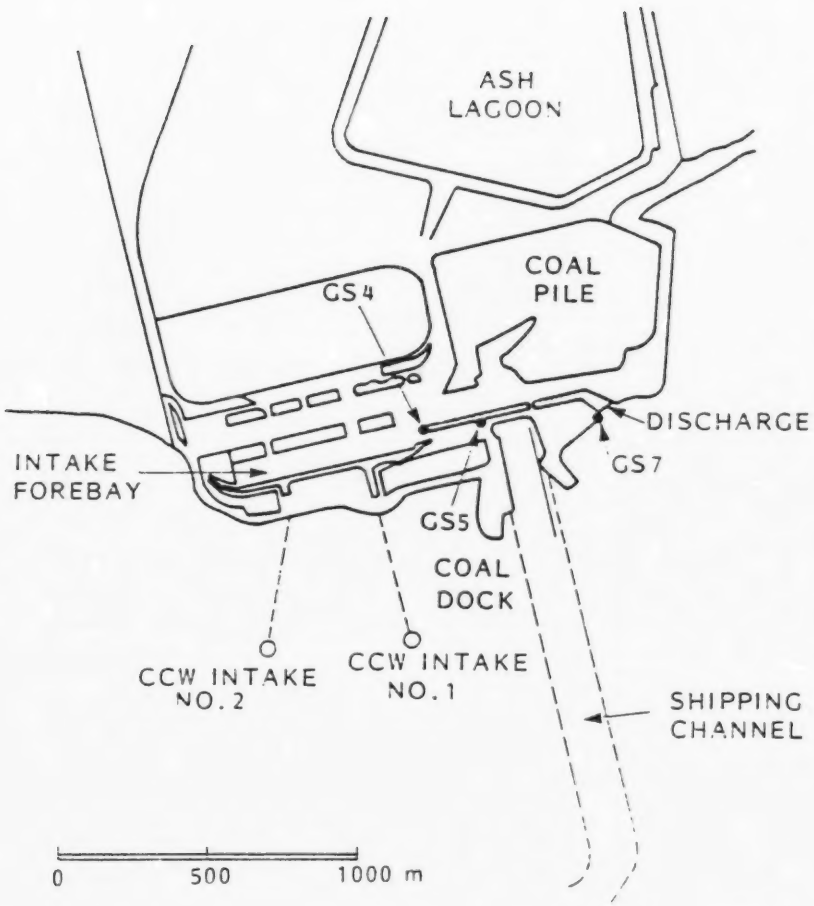


FIGURE 2

GENERATING STATION SAMPLING LOCATIONS FOR ATTACHED ALGAE - NANTICOKE GENERATING STATION - 1981

TABLE 1

SAMPLING LOCATIONS FOR SPECIES COMPOSITION AND BIOMASS

SHORELINE LOCATIONS
L_1 - Mouth of Centre Creek L_2 - Fletcher's Point L_3 - Rip rap adjacent to coal pile L_4 - Texaco L_7 - West of Peacock Point L_8 - Peacock Point
GENERATING STATION LOCATIONS
GS_4 - In the immediate discharge GS_5 - In the immediate discharge downstream from the tempering pumps GS_7 - At the mouth of the discharge channel

location in each month from April to October, placed in a dark plastic bag and frozen until the time of analysis. The chlorophyll 'a' was determined by spectrophotometry by Ontario Hydro's Analytic Services.

Thirty-five of the samples submitted for chlorophyll 'a' analysis were accidentally exposed to acid during freeze drying preventing completion of the analysis. Due to the large number of missing samples the data could not be anlaysed. The results are presented in Appendix 1 for purposes of comparison with future years, should the study be repeated.

3. Elemental Composition

Triplicate 5 g samples of attached algae were collected monthly from April to November at the discharge (GS_4 and GS_5), Centre Creek (near Stelco, L_1), Texaco (L_4) and Peacock Point (L_8) for analysis of the elements listed in Table 2. Analysis of the elements marked by an asterisk was requested by Ontario Hydro. Analysis of the remainder was requested by Ministry of the Environment since these data were to be included in a Ministry study of elemental composition of algae throughout Ontario. Most of the elements requested by Ontario Hydro were metals which could potentially be emitted by Hydro or Stelco. Silicon was included to provide an estimate of the amount of surface debris attached to the algae. This is of interest since previous studies attributed the large variance in metal levels

TABLE 2

ELEMENT CONCENTRATIONS DETERMINED IN THE ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981

Element	Units of Measurement	Analytical Methods
*Aluminum	µg/g dry weight	acid digestion, ICAP
*Cobalt	µg/g dry weight	acid digestion, ICAP
*Iron	µg/g dry weight	acid digestion, ICAP
Magnesium	µg/g dry weight	acid digestion, ICAP
Nitrogen	mg/g dry weight	total Kjeldahl digestion
*Selenium	µg/g dry weight	acid digestion, flameless AA
*Vanadium	µg/g dry weight	acid digestion, ICAP
*Arsenic	µg/g dry weight	acid digestion, flameless AA
*Cadmium	µg/g dry weight	acid digestion, ICAP
*Chromium	µg/g dry weight	acid digestion, ICAP
Mercury	µg/g dry weight	acid digestion, cold vapour flameless AA
*Molybdenum	µg/g dry weight	acid digestion, ICAP
*Lead	µg/g dry weight	acid digestion, ICAP
*Silicon	% dry weight	XRF
*Zinc	µg/g dry weight	acid digestion, ICAP
*Boron	µg/g dry weight	colormetric
*Copper	µg/g dry weight	acid digestion, ICAP
*Nickel	µg/g dry weight	acid digestion, ICAP
Phosphorus	mg/g dry weight	total Kjeldahl digestion
*Sulphur	% dry weight	XRF
Calcium	µg/g dry weight	XRF

* analyses requested by Ontario Hydro
ICAP - Inductively coupled argon plasma emission spectrometry
XRF - X-ray fluorescence
AA - Atomic absorption

NOTE: For those elements requiring acid digestion a mixture of perchloric and nitric acids was used for all samples, except those collected on September 30 and October 29. Nitric acid alone was used on the later samples.

between replicates to the presence of surface debris on some samples (Ontario Hydro Research Division Report No 80-147-K, Ontario Hydro Research Division Report No 81-165-K). In aquatic macrophytes, surface contaminants have been shown to account for as much as 40% of the measured metal concentrations (Patrick and Loutit 1977, cited in Taylor et al 1982). At present, however, there are no satisfactory methods of removing surface debris from attached algae. Silicon can only provide a rough guide to the amount of surface debris since it includes not only silicon present in surface contaminants such as minerals and frustules of epiphytic diatoms, but also silicon actually present in plant tissue (Hutchinson 1975).

The samples were rinsed with distilled water, oven dried at 50°C and sent to Ministry of the Environment for determination of element content. The techniques used and the units reported are summarized in Table 2. For those elements requiring acid digestion a mixture of perchloric and nitric acids was used for all samples, except those collected on September 30 and October 29. Nitric acid was used for the samples from the last two collection dates. This change in digestion procedure was not expected to affect the results of any element, except aluminum. Nitric acid may have been a less efficient extractor of aluminum than the nitric-perchloric mixture (Frank Darcel, MOE, personal communication).

4. Statistical Methods

A multivariate approach was taken in analyzing the element concentration data. Multivariate methods are trend seeking techniques which incorporate all the variables (in this case, all the elements) into the analysis at the same time. The types of trends sought and the mathematical procedures used vary according to the multivariate method. There were two multivariate methods used in this study (principal components analysis and discriminant analysis) which are outlined below.

Principal Components Analysis

The aim of principal components analysis is to summarize a set of observations while retaining as much of the information in the entire data set as possible. It can be visualized in terms of a geometrical model in which the samples are represented as points in a space with the variables (the elements) as coordinate axes. If there are correlations among the elements, the samples will be dispersed in a hyperellipsoid. Such a representation is redundant since some of the information about sample location in the space is carried by more than one variable. During principal components analysis the samples are redescribed by a new set of axes (or variables) with the following properties:

1) The first axis accounts for as large a percentage of the variance as possible.

2) The second and subsequent axes successively account for as much as possible of the variance remaining after extraction of the previous axes, subject to the constraint that they are orthogonal to those extracted earlier. Orthogonality is the geometric equivalent of linear independence, zero correlation and lack of redundancy (Dale 1975).

Geometrically, this involves a rotation of the original axes to the principal axes of the hyperellipsoid. The number of variables (axes) used to describe the samples may be reduced by disregarding those axes with small variances without significantly altering the configuration of points in the space.

The computational details of principal components analysis are described by Cooley and Lohnes (1971) and Tatsuoka (1971).

Input to the principal components analysis consisted of fifty samples for which measurements of 20 elements were available. Values which were below the detection limit were set to half the detection limit. The analysis was done by computer using the SAS program PRINCOMP (SAS Institute Inc, 1982). The analysis yields a set of linear combinations, each of which defines a new variable (component) for the samples in terms of the original 20 elements. The coefficients of the elements in the linear functions are known as factor loadings. They measure the correlation between the new variables (components) and the original variables (elements), and, consequently, range from -1 to +1. The square of a factor loading is proportional to the variance of an element that is accounted for by a component.

The coordinates (component scores) of the samples in the component space are obtained by summing the products of the factor loadings and the corresponding standardized element concentration in each sample for each component.

Discriminant Analysis

Discriminant analysis refers to several different types of analysis. The objective of the procedures used here was to select a subset of the elements that best reveals the differences among the three sampling locations. The first procedure used was the SAS program STEPDISC (SAS Institute Inc 1982). It is based on a stepwise selection process in which variables with a specified minimum capacity to distinguish between the three groups are sequentially added to the model. At each step the variable with the most discriminatory power is selected, while at the

same time the variables previously added are tested to see whether they still meet the discriminatory criterion. When all variables in the model meet with the criterion to stay and none of the others meet with the criterion to enter, the stepwise selection process stops. The discriminatory power of the variables selected was assessed by reclassifying the algal samples into three groups and comparing these groups with the original groups. The reclassification was based on the scores of the samples calculated from linear functions of the variables computed by the SAS program DISCRIM (SAS Institute Inc, 1982). The composition of the derived groups will be similar to the original groups if the discriminatory power of the subset of variables selected by the STEPDISC procedure is high. The variables were standardized to zero mean and unit variance prior to the analyses, since the results using raw data may be influenced by the absolute magnitude of the element concentrations.

RESULTS AND DISCUSSION

Species Composition

The species composition of the filamentous algae identified at Nanticoke GS in 1981 is shown in Appendix 2. For purposes of comparing the composition at lakeshore sampling locations with the generating station locations, a mean value was calculated for the two groups and plotted in Figure 3. On each sampling occasion, the same species were usually present at both the lakeshore and generating station locations, but their proportionate abundance usually differed. From April to August the proportion of *Cladophora* and *Oedogonium* was generally lower at the generating station locations than at the lakeshore locations, while the proportion of *Ulothrix* sp and the Zygnematales (*Zygnema*, *Spirogyra* and *Mougeotia*) was generally higher. The lower proportion of *Cladophora* and the higher proportion of Zygnematales at the generating station is consistent with observations from previous years of the study (Kirby and Dunford 1981). This was attributed to the sheltered conditions within the discharge which may be less suitable for *Cladophora* than the exposed lakeshore. *C. glomerata* grows well only in areas with considerable water movements (Neil 1975). At the same time, the protected nature of the discharge may be more suitable for species such as *Zygnema*, *Spirogyra* and *Mougeotia* which can form rhizoidal branches and become weakly attached to the substrate (Prescott 1962). The prominence of *Oedogonium* at the lakeshore in 1981 is atypical of previous trends, and is of unknown significance.

There were six species of epiphytic algae collected at Nanticoke GS in 1981 (Appendix 2), but only three species (*Cymbella* sp, *Rhoicosphenia curvata* and *Cocconeis* sp) were

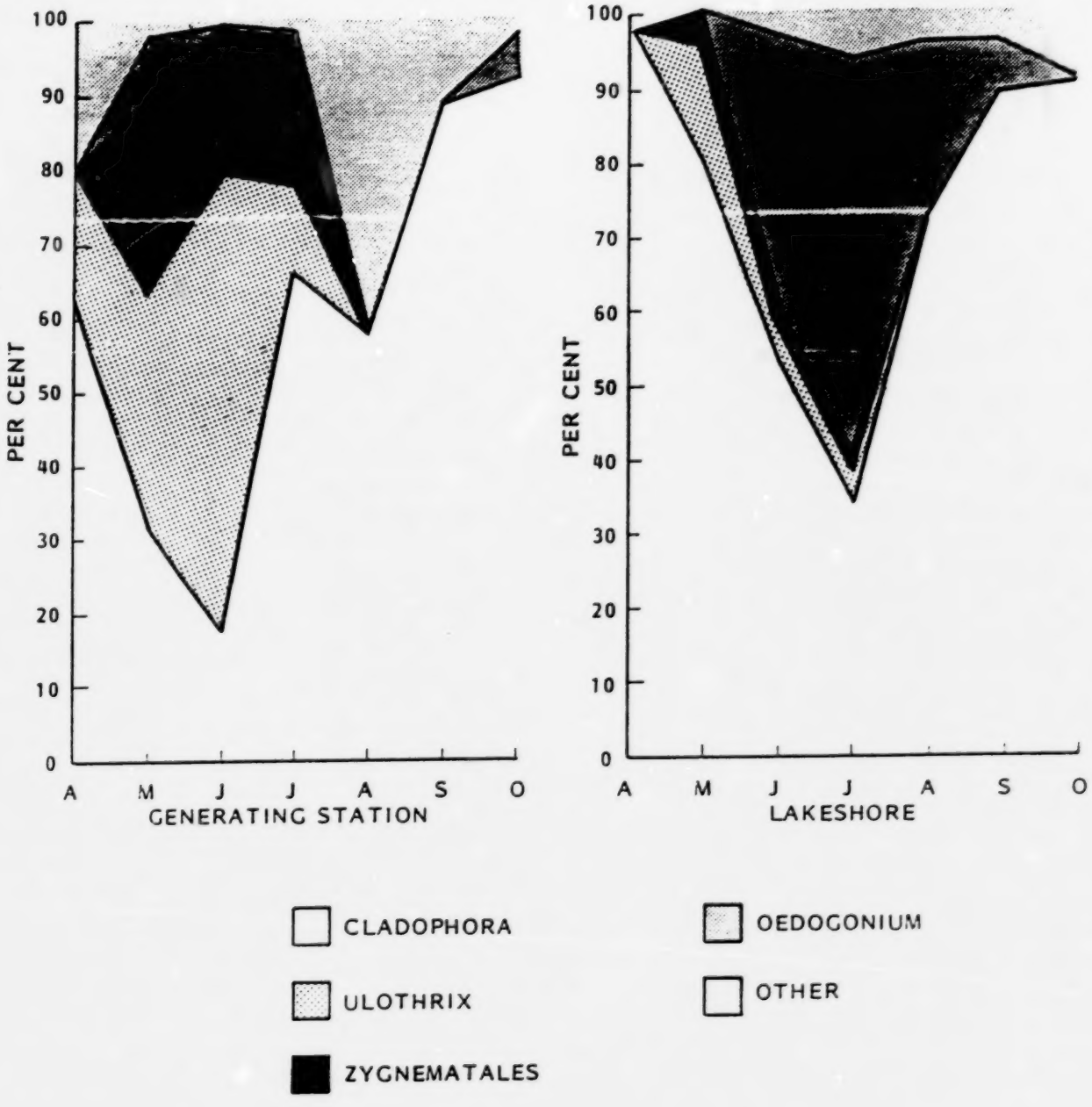


FIGURE 3

PERCENT COMPOSITION OF FILAMENTOUS ALGAE FROM LAKESHORE AND GENERATING STATION LOCATIONS
NANTICOKE GENERATING STATION - 1981

common. None of the species exhibited a distinct temporal or spatial trend. These common species were also frequent in previous years (Kirby and Dunford 1981).

Biomass

The ash free dry weights of the attached algae from the six lakeshore sampling locations and the three generating station locations are presented in Appendix 3. The sample weights were usually less than 150 g/m^2, but ranged as high as 6915 g/m^2 for one sample taken from the immediate discharge downstream from the tempering pumps (GS_5). This sample and one other taken from Fletcher's Point (L_2) in June (911.12 g/m^2) were considered outliers and were omitted from the data analyses. The data were analyzed by 2-way analysis of variance (month x location) in which the sample locations were treated either as individual units giving a total of nine locations or as members of the lakeshore or generating station group giving a total of two locations. In both cases the null hypothesis was that there were no differences in mean biomass between locations, but in the first analysis no distinction is made between locations inside and outside the influence of the thermal discharge as there is in the second. The data were logarithmically transformed ($\log_e$) to satisfy the homogeneity of variance assumption of ANOVA (Sokal and Rohlf 1969). A value of 0.0001 g/m^2 was assigned to samples in which no algae were found prior to the transformation. All analyses were done by computer using the SAS program GLM (SAS Institute Inc, 1982).

A summary of the ANOVA's is presented in Tables 3 and 4. As a guide to interpreting the results the values of the monthly geometric mean biomass (mean of data on $\log_e$ scale) have been plotted in Figures 4 and 5. The location x month interaction term was statistically significant ($p = 0.05$) in both analyses. This indicates that the differences in biomass between locations (either individually or grouped) were not constant but varied according to the month in which the samples were collected. This result is not unexpected given the diversity of seasonal patterns in biomass apparent in Figure 4. To determine whether or not non constant differences in biomass existed between the locations for the entire sampling period, the coefficients in the linear model underlying the ANOVA's were estimated and the interaction term tested for significance using a Student's T test. The linear model may be formulated as follows.

$$\log_e (\text{ash free dry weight})_{ijk} = \mu + L_i + M_i + LM_{ij} + \varepsilon_{ijk}$$

where L_i = fixed location effect, i = 1...9 when the locations are considered as individual units

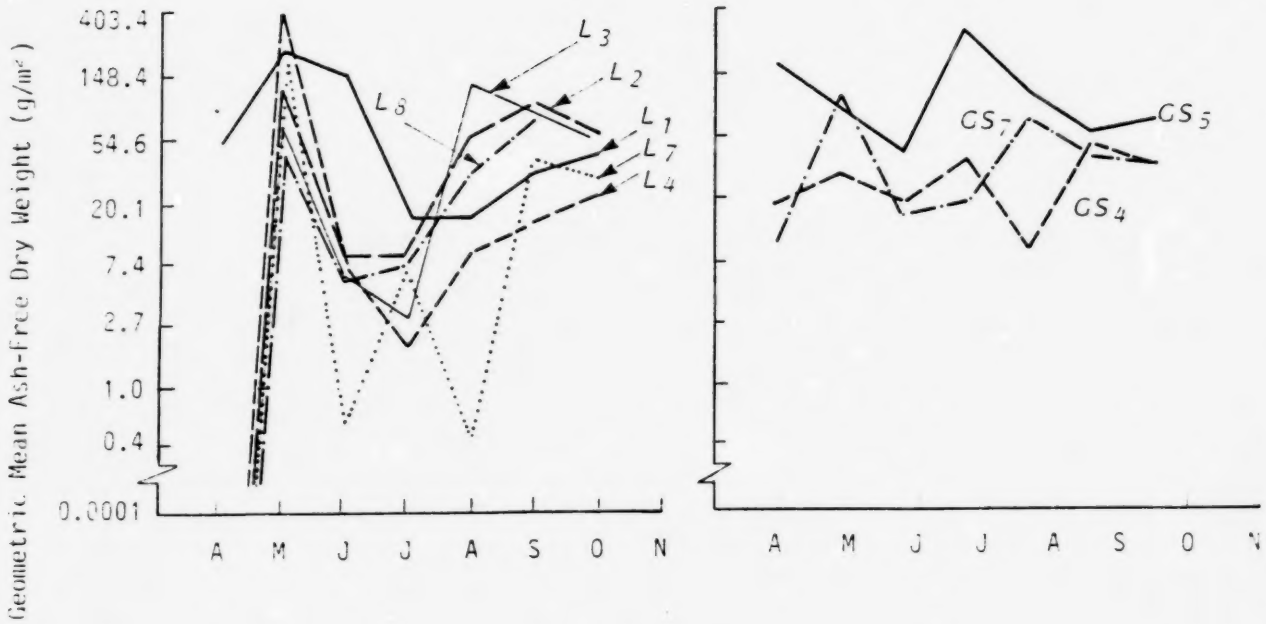


FIGURE 4

MONTHLY GEOMETRIC MEAN BIOMASS OF THE ATTACHED ALGAE SAMPLES
NANTICOKE GS - 1981

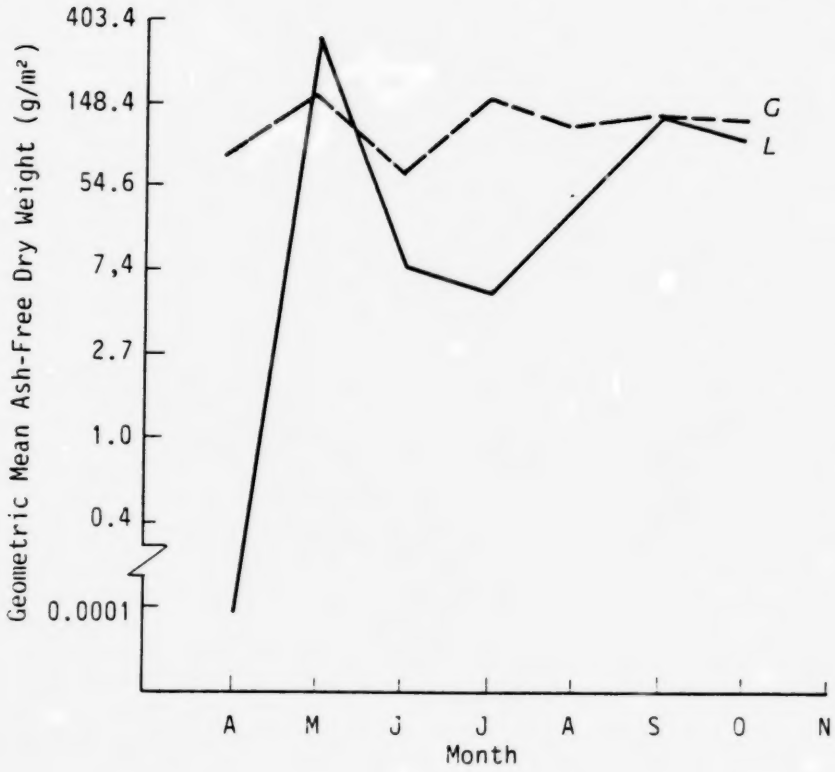


FIGURE 5

MONTHLY GEOMETRIC MEAN BIOMASS OF THE ATTACHED ALGAE
AT THE LAKESHORE AND GENERATING STATION
NANTICOKE GS - 1981

i = 1,2 when the locations are grouped into the generating station or lakeshore categories.

M_j = fixed month effect, j = 1,7 (April to October)

LM_{ij} = location x month interaction

ε_{ijk} = error k = 1... the # of replicates.

TABLE 3

ANALYSIS OF VARIANCE OF LOG_e TRANSFORMED DATA WITH TWO OUTLIERS DELETED
(each location was treated separately)

Source	DF	SS	F Value	P > F
location	8	358.69	75.52	0.001
month	6	825.60	231.77	0.001
location x month	47	919.72	32.96	0.001
error	119	70.65		
total	180	2544.16		

TABLE 4

ANALYSIS OF VARIANCE OF LOG_e TRANSFORMED DATA WITH TWO OUTLIERS DELETED
(the locations were grouped into lakeshore and generating station categories)

Source	DF	SS	F Value	P > F
location	1	163.77	40.76	0.001
month	6	599.17	24.85	0.001
location x month	6	473.73	19.65	0.001
error	167	670.99		
total	180	2544.16		

The interaction term LM_{ij} would have an expected value of zero if the same seasonal pattern were apparent at all locations, ie, if the lines in Figures 4 and 5 were parallel. The

estimates of interaction indicated that the differences between the locations were relatively constant, except in April and July. No algae were observed at any lakeshore sampling location in April, except L_1, while good growth was observed at all generating station locations. This suggests that the algae at the generating station begin growing earlier in the year than the algae at the lakeshore locations. The earlier growth of the algae at the generating station was observed in previous years of the study and was attributed to the ice free conditions existing in the discharge over the winter months (Kirby and Dunford 1981). Benda (1976) similarly documented that *Cladophora glomerata* began growth earlier in the spring in the area of a thermal discharge from the Palisades Nuclear Power Plant than in the surrounding areas. The *Cladophora* also persisted later in the fall in the discharge, but died back in mid-summer when the water temperatures exceeded 26°C. A mid-summer die back did not occur at the Nanticoke GS, although the water temperature in the discharge exceeded 26°C for a total of 21 days in August and early September of 1981 (CTS temperature data).

Strong winds and storms may account in part for the interaction in July. The mean biomass at the generating station was higher than at the lakeshore (Figures 4 and 5). Large quantities of *Cladophora* were observed to be washed up on shore and floating freely in shallow water at all the lakeshore locations, but not at the generating station. This suggests that the biomass at the lakeshore locations would have been higher than the measured values, had the algae not been detached. The generating station locations (in particular GS_4 and GS_5) are more sheltered and perhaps less subject to the scouring activity of waves than the lakeshore locations. Following the storms the algae at the lakeshore locations grew rapidly and reached biomass levels similar to those at the generating station in September and October.

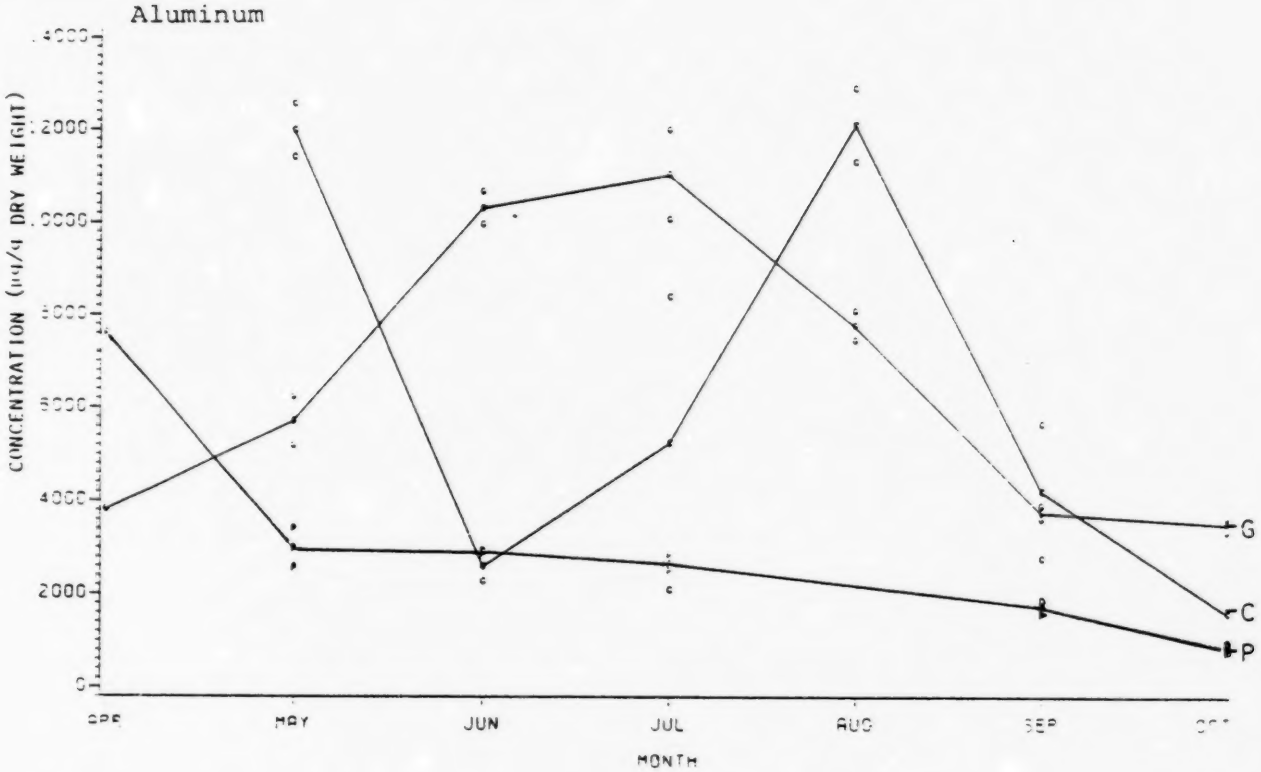
Elemental Composition

The elemental concentrations in the algae are listed in Appendix 4. Only three of the locations, L_8 (the control, Peacock Point), L_1 (Centre Creek) and GS_5 (the discharge downstream from tempering), could be regularly sampled. High water levels and sparse algal growth respectively resulted in the infrequent samples from GS_4 and L_4 (Texaco). Only data from L_1, L_8 and GS_5 were included in the statistical analyses. Several outliers were identified and were omitted from the analyses. These are marked with an asterisk in Appendix 4. Molybdenum data were also excluded since they were unreliable (Dr. J. Pimenta, Ministry of the Environment, personal communication). Data from GS_4 and L_4 were examined visually and supported the trends revealed from analysis of L_1, L_8 and GS_5.

The mean elemental concentrations in the algae from L_1, L_8 and GS_5 have been plotted in Figures 6 to 15. The data are characterized by considerable spatial and temporal variability, but certain trends are apparent. The algae from both Centre Creek and the generating station contained higher mean concentrations of the following elements than the algae from Peacock Point (the control, L_8) on all or all, but one, sampling occasions: arsenic, aluminum, cobalt, zinc, phosphorus iron, silicon, nickel, vanadium, mercury and chromium. The elements which were lower at the generating station than at Peacock Point on one occasion were lower in April, while those which were lower at Centre Creek than at Peacock Point on one occasion were generally lower in June. Copper was the only element which was substantially elevated at GS_5 relative to both Peacock Point and Centre Creek. Selenium was generally higher in the algae from Centre Creek than in the algae from Peacock Point. Boron was the only element which was present at consistently higher concentrations in the algae from Peacock Point than in the algae from either Centre Creek or the generating station.

The list of elements which were found in higher concentrations in the algae from the generating station than in the control is similar to that found in 1979 (Ontario Hydro Research Division Report No 81-165-K). However, in 1979 the following additional elements were also found in elevated levels in the algae from the discharge: manganese, calcium, selenium, magnesium and cadmium. Of these, only manganese was not measured in 1981. Three of the remaining four (cadmium, selenium and magnesium) were found at higher concentrations in the algae from the generating station than in the controls on some occasions in 1981, but were not consistently higher. Had the sampling been done only once in 1981 as it had in 1979, it is possible that elevated levels of these metals would have been detected, if the algae were sampled at an appropriate time. In 1979, higher concentrations of boron were also found in the controls than in samples from both Lakeview and Nanticoke (Ontario Hydro Research Division Report No 81-165-K).

In 1979 some algal filaments were contaminated with particulates which were thought to produce large differences in the element concentration of replicates and gave misleading results. In 1981 silicon concentration was measured as a rough guide to surface contamination. The concentration of silicon in the algae from both the generating station and Centre Creek was generally higher than at Peacock Point. This would suggest that surface contamination may have also been a problem in 1981. However, it is not known what percentage of the silicon was found on the surface of the algae and what percentage was found internally.



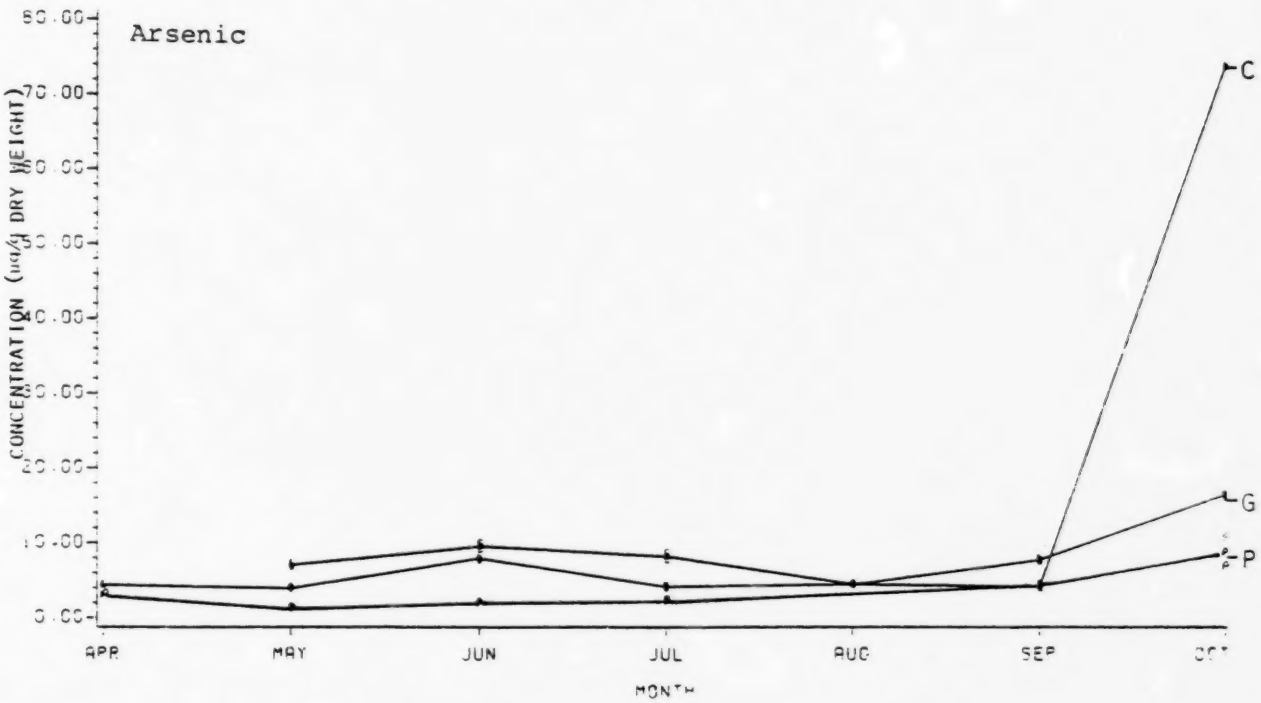


FIGURE 6

MEAN CONCENTRATION (±1SE) OF ALUMINUM AND ARSENIC IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

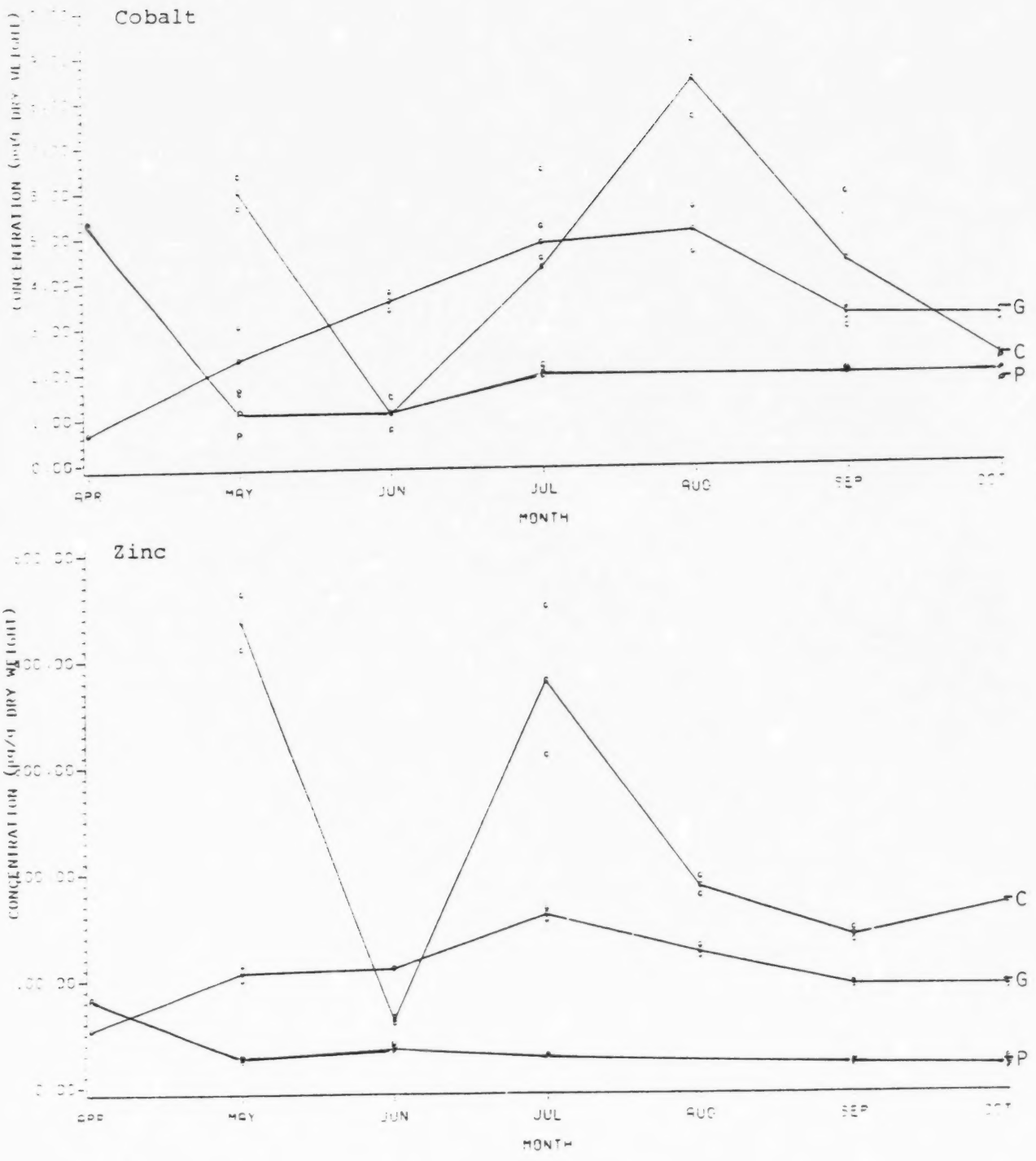


FIGURE 7

MEAN CONCENTRATION (±1SE) OF COBALT AND ZINC IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

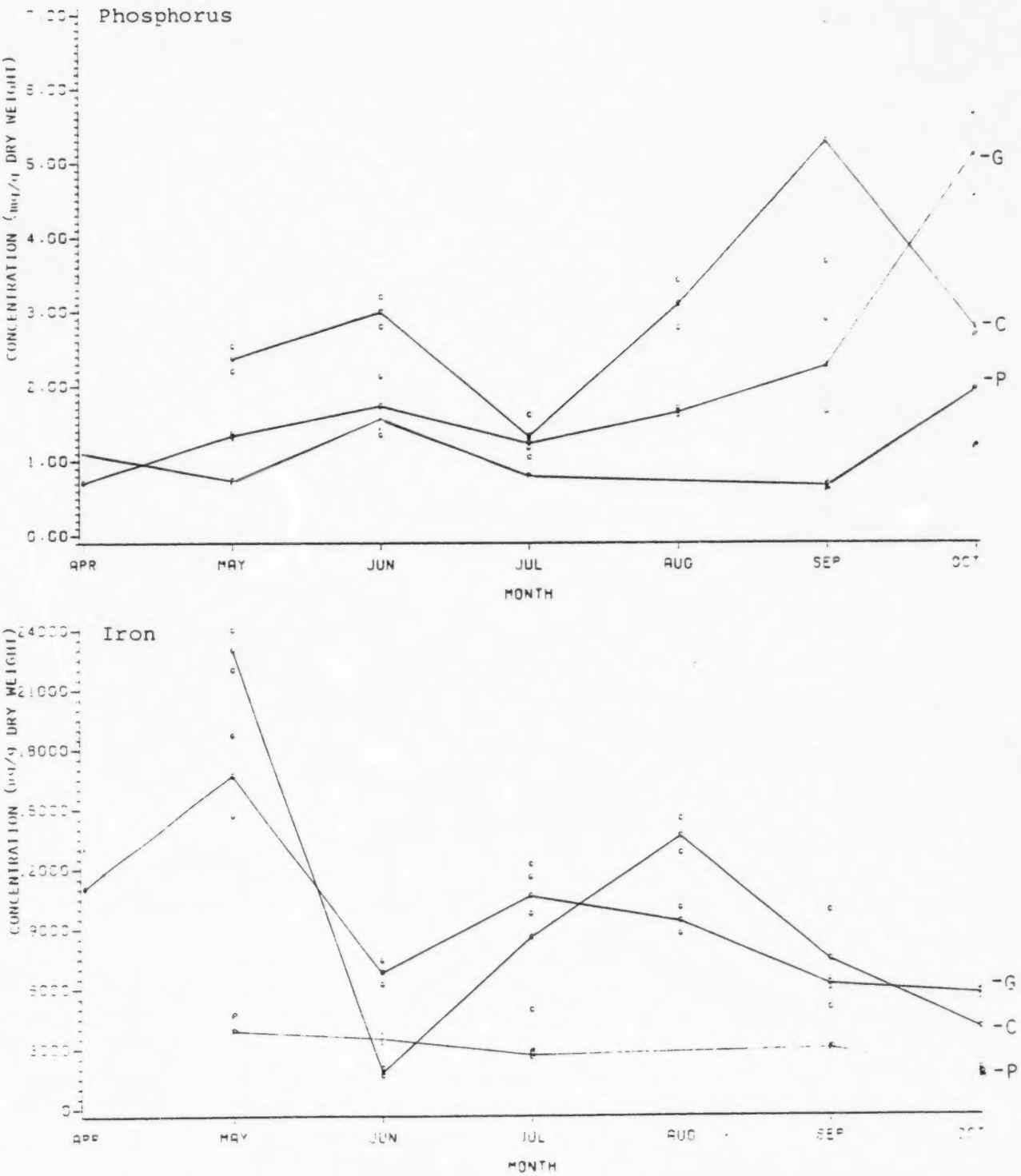


FIGURE 8

MEAN CONCENTRATION (±1SE) OF PHOSPHORUS AND IRON IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

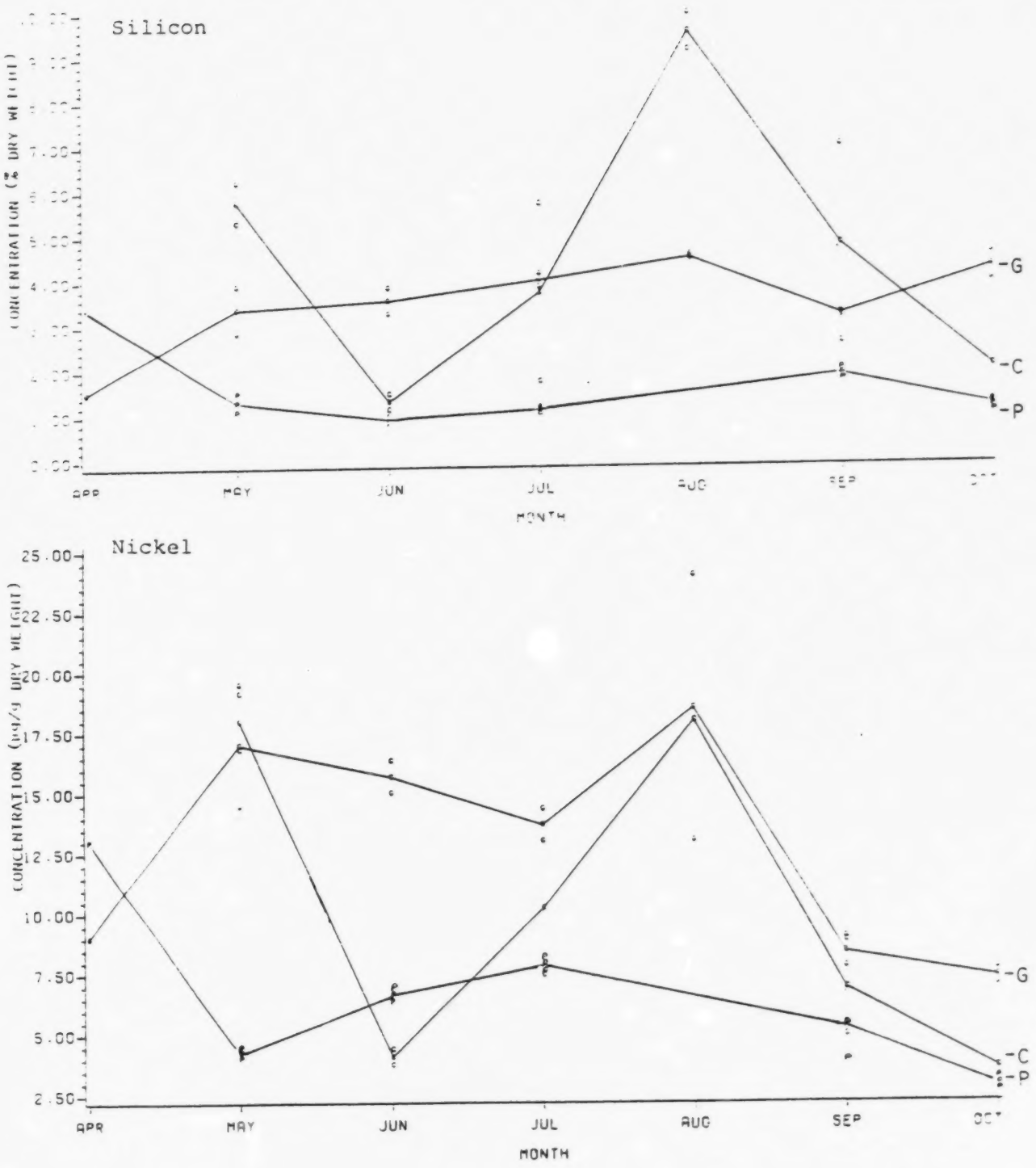


FIGURE 9

MEAN CONCENTRATION (±1SE) OF SILICON AND NICKEL IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

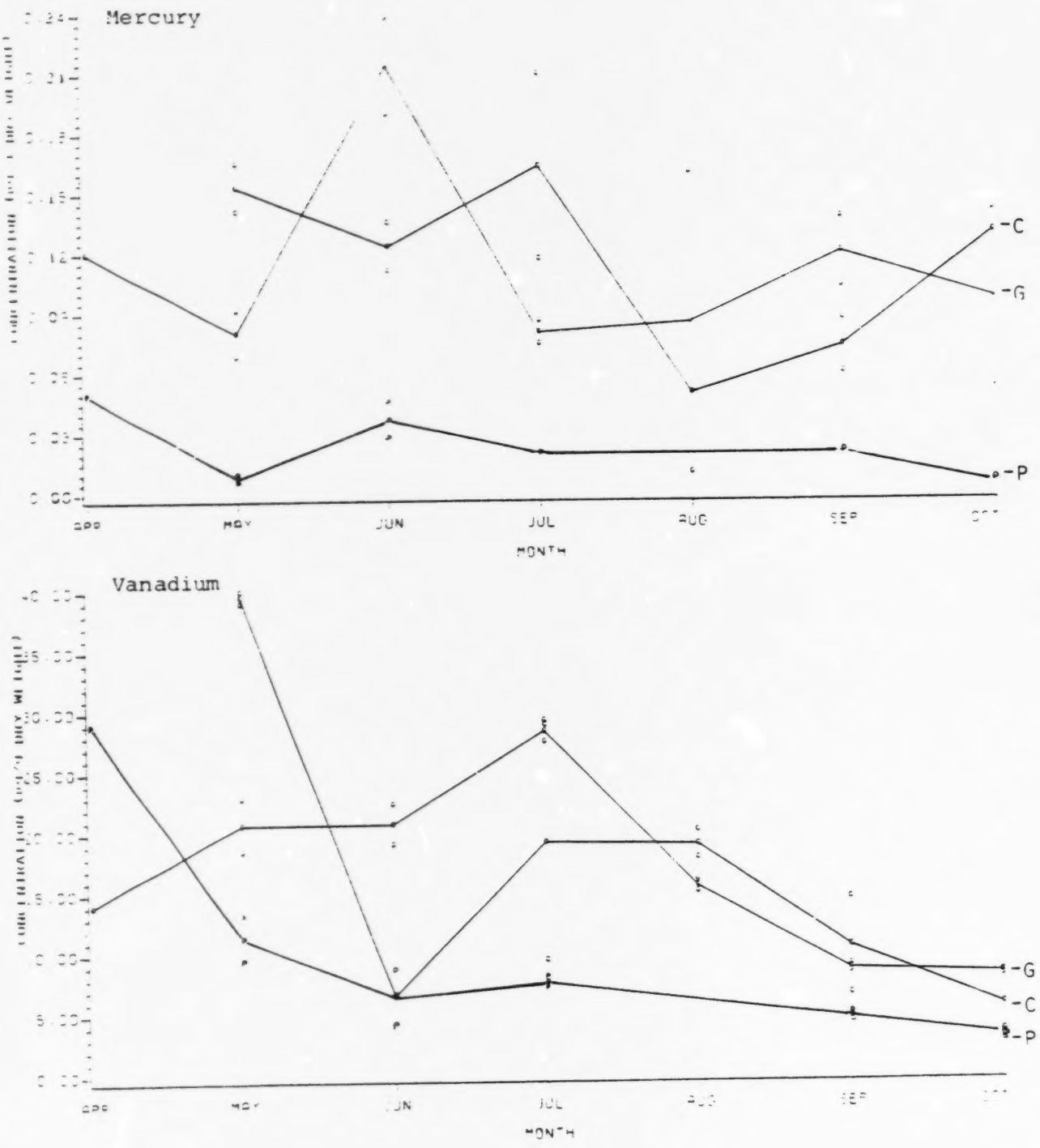


FIGURE 10

MEAN CONCENTRATION (±1SE) OF MERCURY AND VANADIUM IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

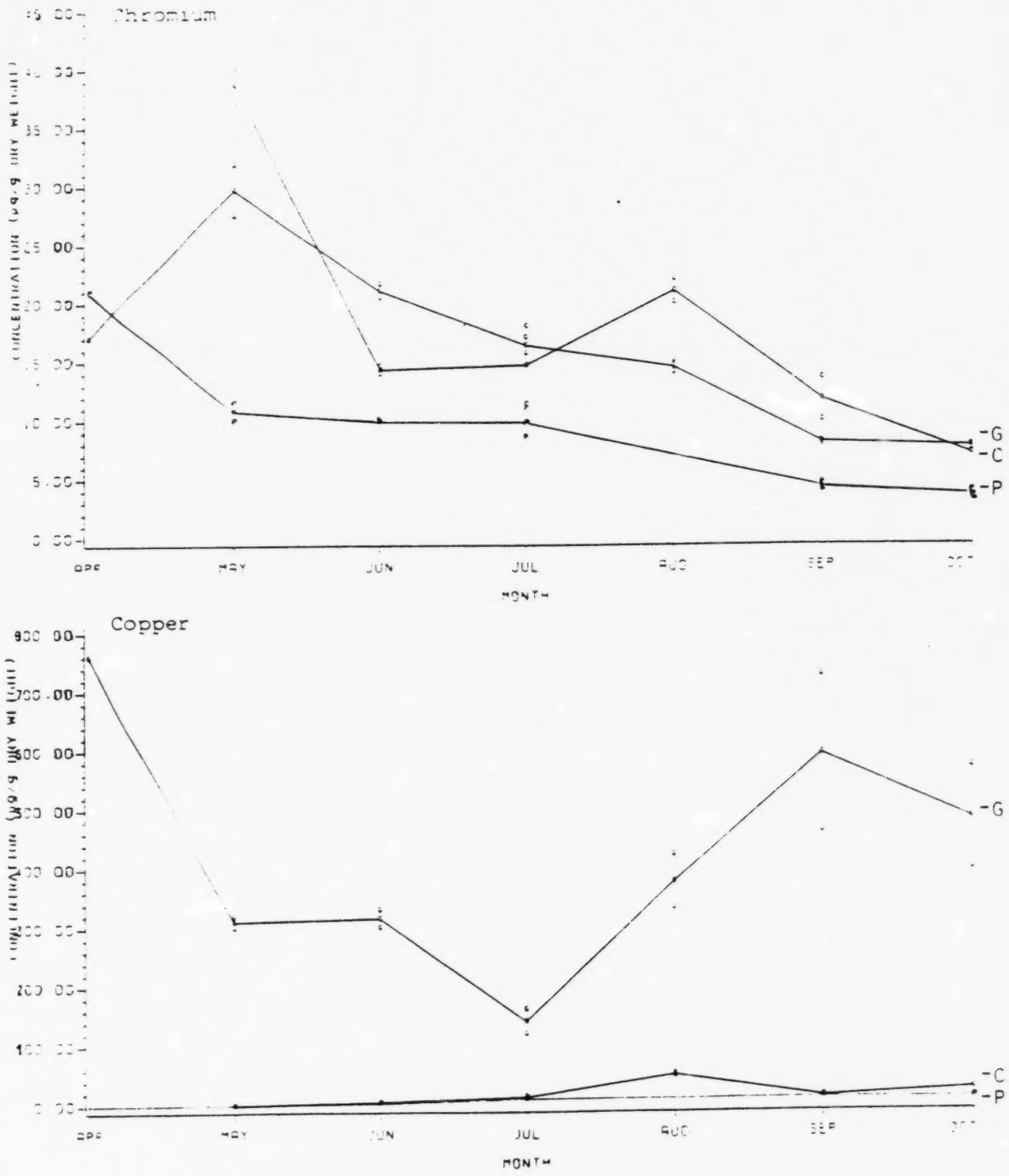


FIGURE 11

MEAN CONCENTRATION (±1SE) OF CHROMIUM AND COPPER IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

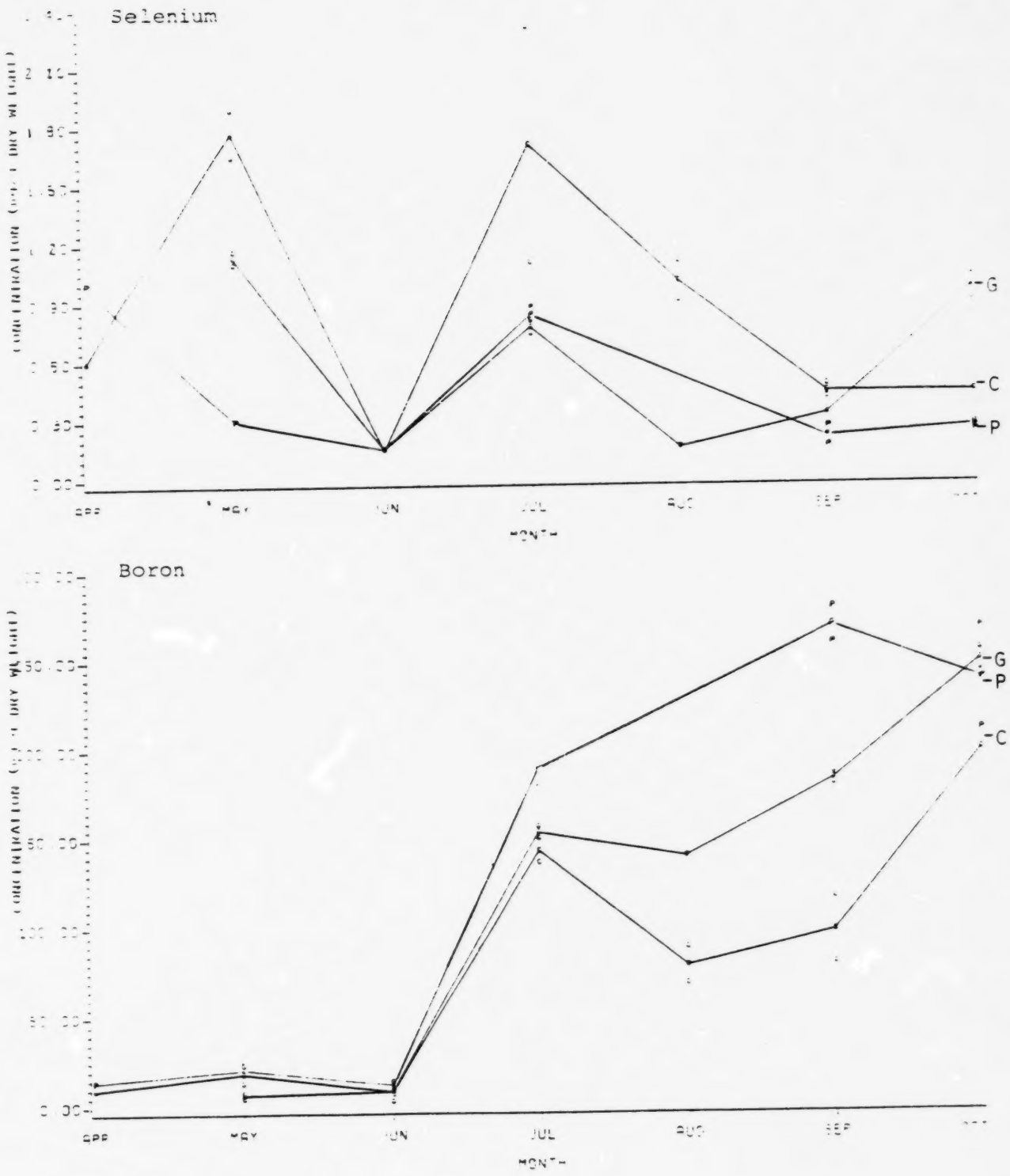


FIGURE 12

MEAN CONCENTRATION (±1SE) OF SELENIUM AND BORON IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

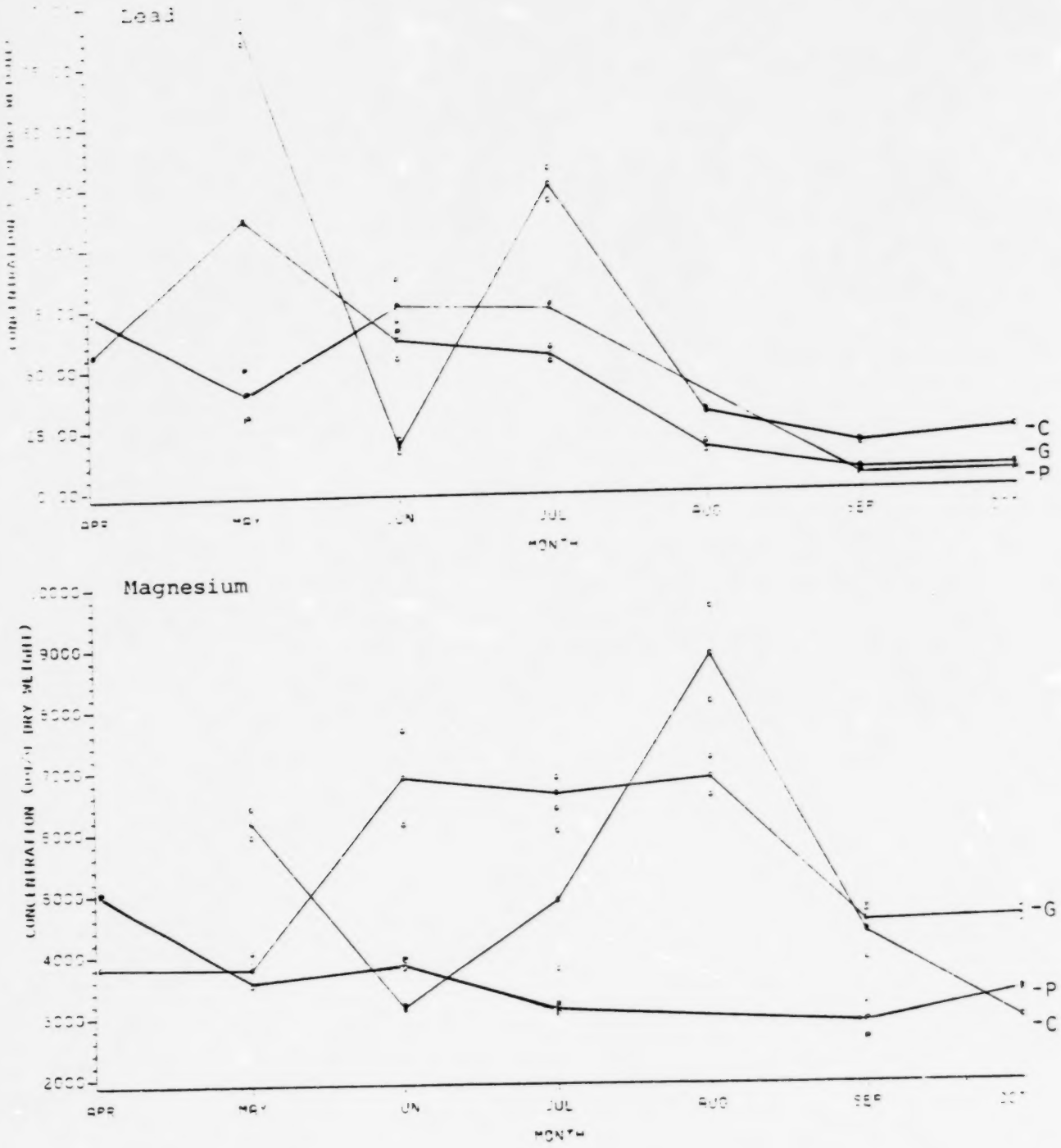


FIGURE 13

MEAN CONCENTRATION (±1SE) OF LEAD AND MAGNESIUM IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

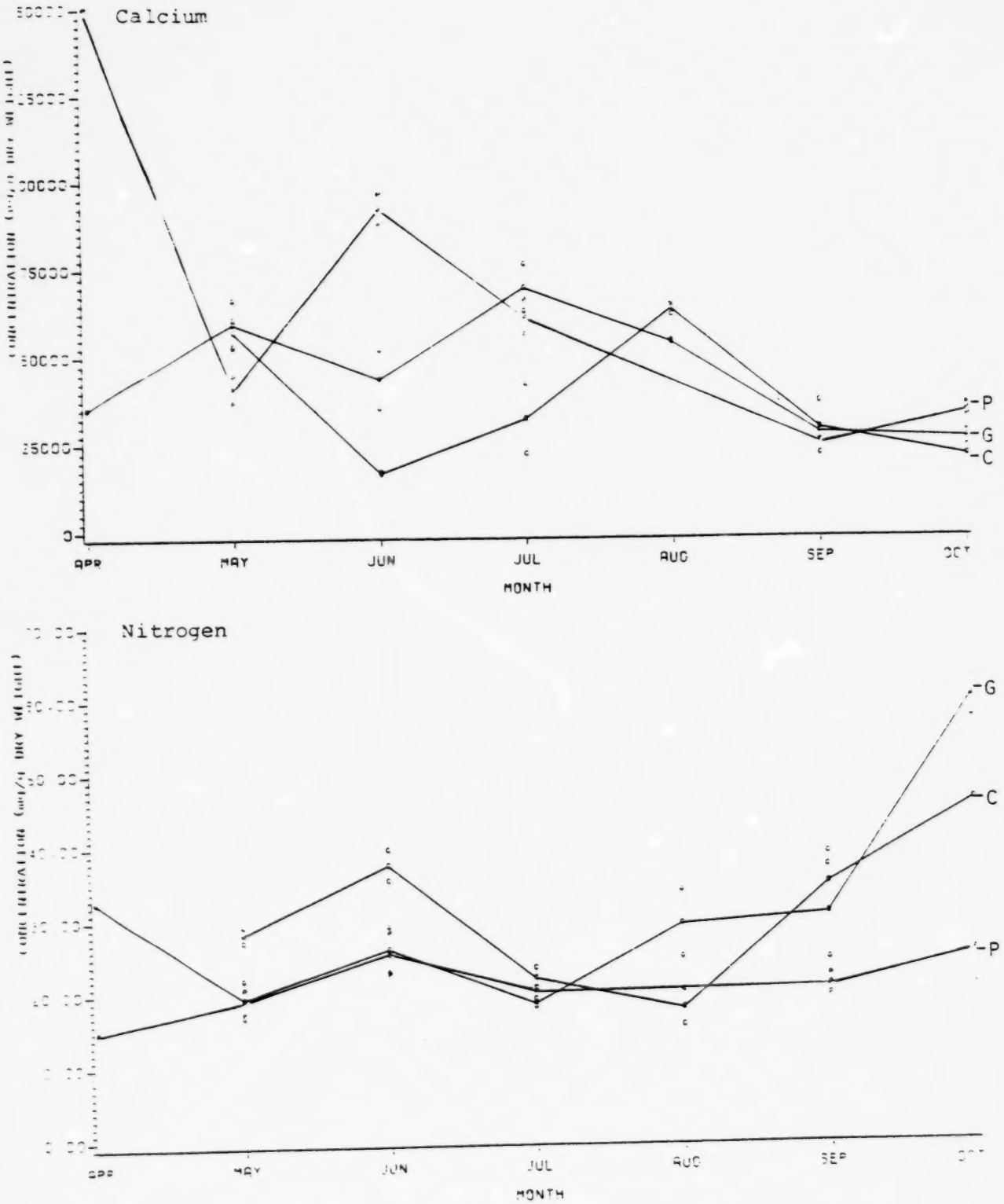
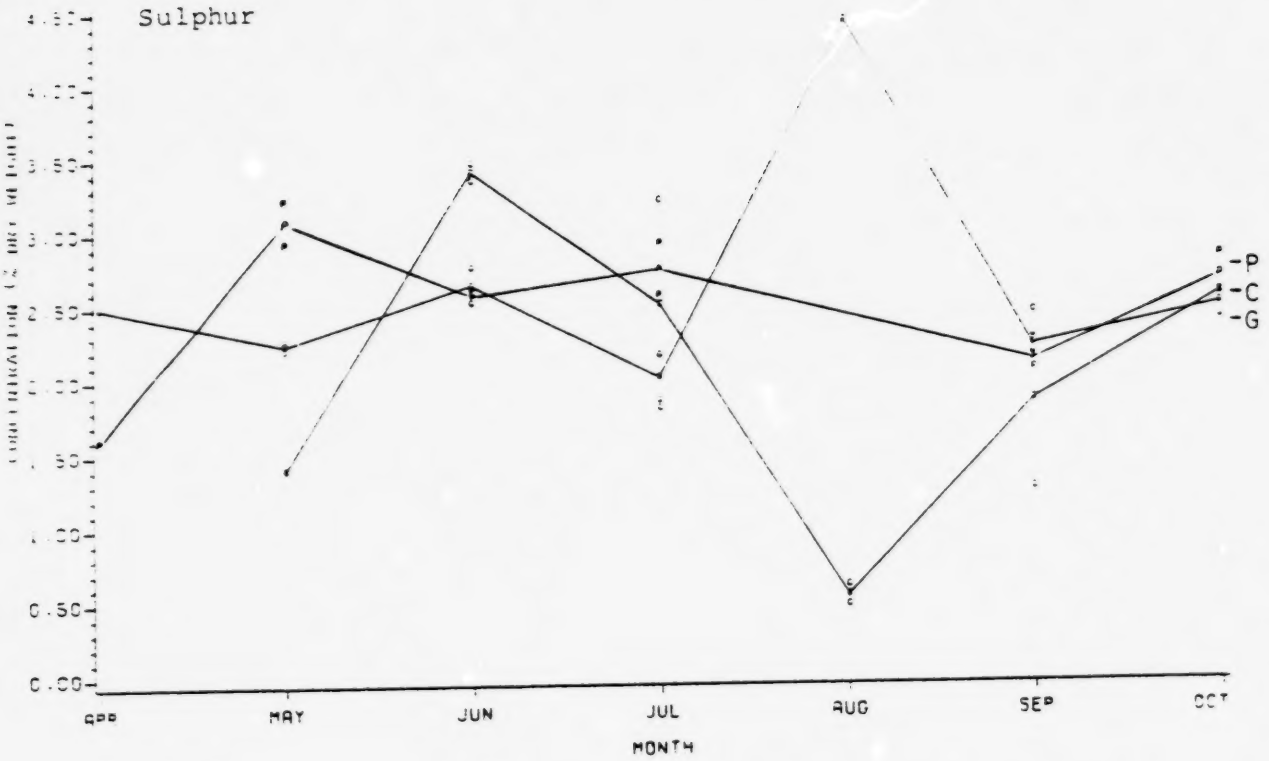


FIGURE 14

MEAN CONCENTRATION (±1SE) OF CALCIUM AND NITROGEN IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION



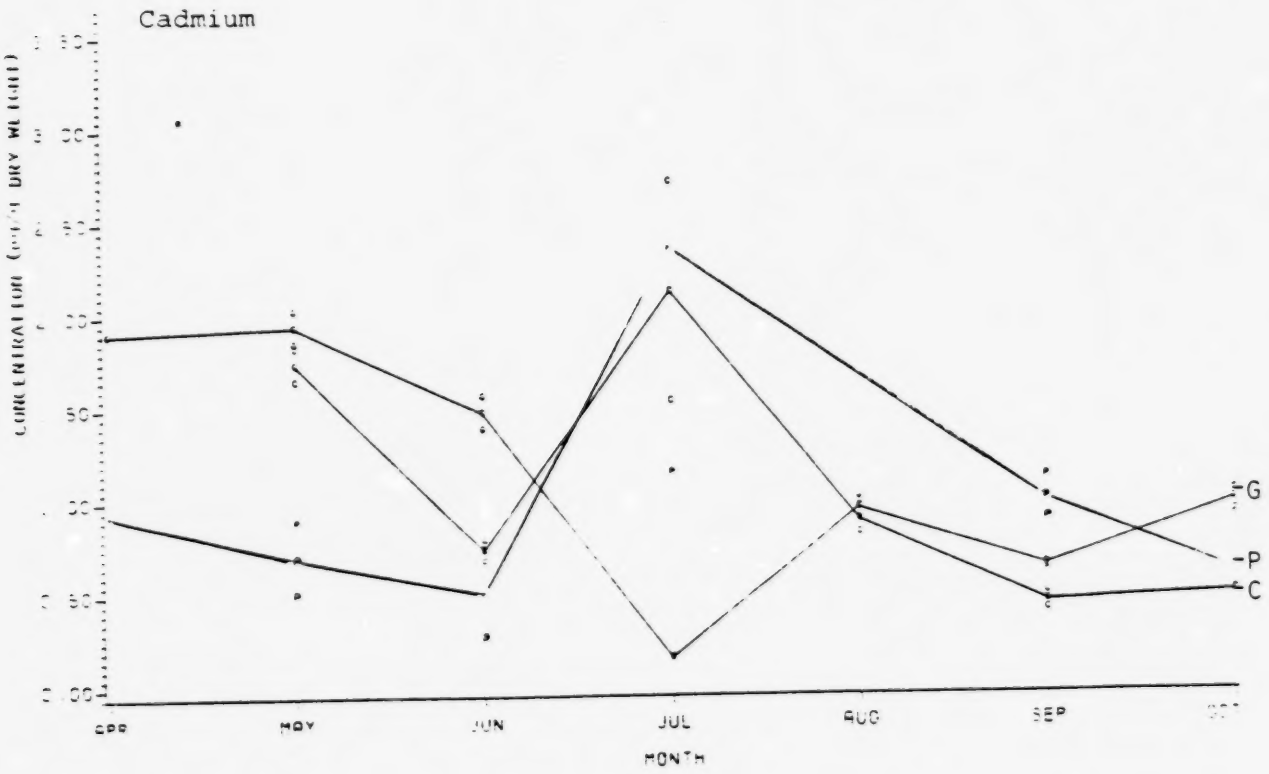


FIGURE 15

MEAN CONCENTRATION (±1SE) OF SULPHUR AND CADMIUM IN ATTACHED ALGAE FROM THE NANTICOKE STUDY AREA - 1981 - C-CENTRE CREEK, P-PEACOCK POINT, G-GENERATING STATION

The elemental concentration data were analyzed by two multivariate trend seeking techniques, namely, principal components analysis and discriminant analysis. The results of these two analyses are presented below.

Principal Components Analysis

The first two principal components respectively accounted for 41.6% and 14.6% of the total variance. The factor loadings have been plotted in Figure 16 and the factor scores in Figure 17. The trends in the factor loadings are not well pronounced. The range on the first component is not very broad; the values go from only -0.18 to 0.325. This indicates that no more than 10.6% of the variance of any individual element is accounted for by this component. There is some distinction between those elements which were generally found at higher concentrations in the algae from the generating station and Centre Creek than in the controls and those elements which were not. Included in the former group were silicon, cobalt, zinc, aluminum, iron, nickel, vanadium and chromium, all of which have loadings of greater than 0.25. Phosphorus, arsenic and mercury were also part of this group, but had loadings of less than 0.25. Given the pattern in the loadings it is inevitable that the lowest scores (Figure 17) are obtained by the control samples whose elemental concentrations are at what are considered ambient or background levels for the Nanticoke area, while the highest scores are obtained by the samples from locations influenced by industrial wastes. The first component may therefore be interpreted as reflecting the contrast between contaminated and uncontaminated environments. A decrease in the level of metal contamination in the algae over the growing season is suggested by the general decrease in the scores of the samples from both Peacock Point and the industrialized locations on the first component from April to October.

The range of loadings on the second component is greater than on the first, with the two highest loadings being calculated for phosphorus (0.4557) and nitrogen (0.4476) and the lowest for calcium (-0.3110). This may suggest a possible association of this component with nutrient status, but the association is not perfect since some nutrients (eg, magnesium and sulphur) have near zero loadings and some non-nutritive elements have high (arsenic) or low (lead) loadings. Some separation is evident between the samples from Peacock Point and the samples from the generating station and Centre Creek, particularly for those collected in September and October. A seasonal trend is again suggested by the general increase in the scores on the second component from April to October.

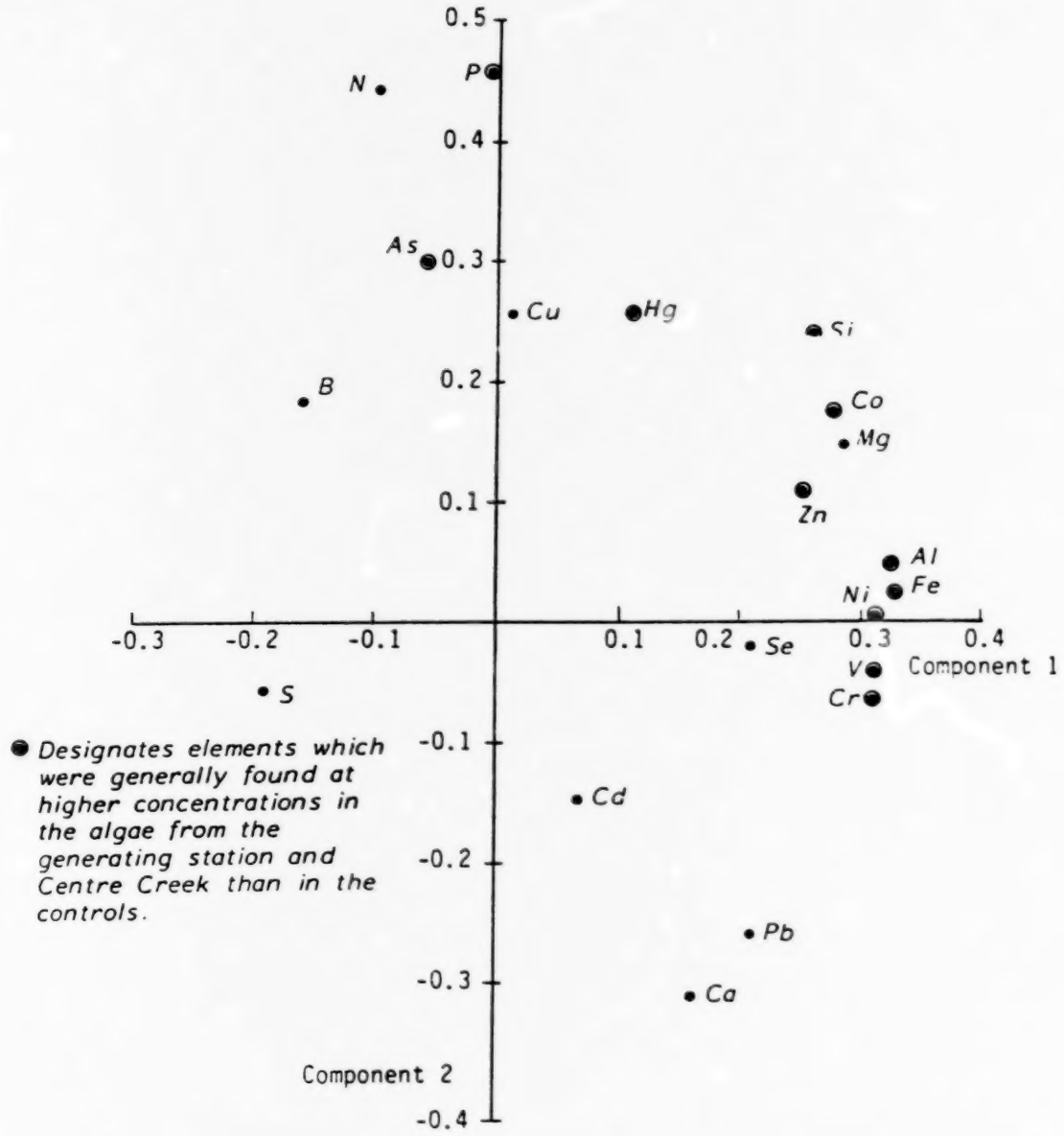


FIGURE 16

FACTOR LOADINGS OF THE ELEMENTS ON THE FIRST TWO PRINCIPAL COMPONENTS

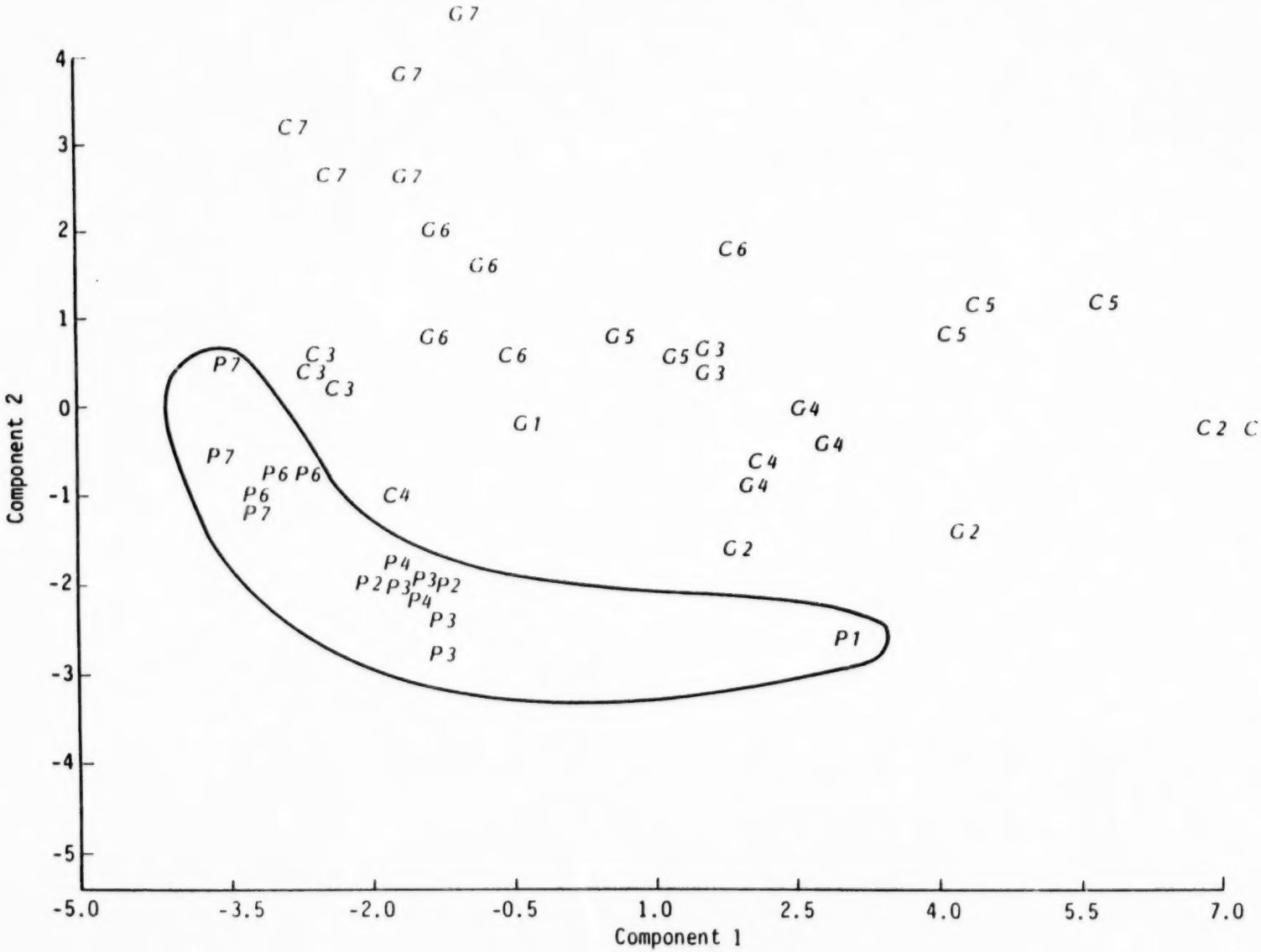


FIGURE 17

FACTOR SCORES OF THE ALGAE SAMPLES ON THE FIRST TWO PRINCIPAL COMPONENTS. THE LETTER DESIGNATES COLLECTION LOCATION AND THE NUMBER, MONTH OF COLLECTION (G-GENERATING STATION, C-CENTRE CREEK, P-PEAKCOCK POINT, 1-APRIL.....7-OCTOBER)

Discriminant Analysis

Four variables were selected for the discriminant model (Table 5). Three of the four (zinc, vanadium and phosphorus) were among the elements which were generally found at higher concentrations in the algae from the generating station and Centre Creek than in the controls. The fourth element (copper) was substantially higher in the algae from the generating station than in the algae from Peacock Point and Centre Creek. The discriminatory power of the four variables is high since only 3 of the 48 samples were misclassified during the reclassification procedure (Table 6). However, of the four variables selected, copper and zinc had a considerably greater discriminatory power than the remaining two as indicated by the F statistic. The concentrations of copper and zinc in the samples have been plotted in Figure 18. Based on these two elements alone, there is a good separation between locations. All the Peacock Point samples cluster near the origin of both axes and overlap very little with the distribution of samples from either the generating station or Centre Creek.

In summary the results of the principal components analysis and the discriminant analysis indicate that there are differences in the element content of the algae from the three sampling locations. In both analyses the most important elements were ones which were generally found at higher concentrations in the algae from industrialized locations than in the controls. These elements include arsenic, aluminum, cobalt, zinc, phosphorus, iron, silicon, nickel, vanadium, mercury, copper and chromium. The major difference in the results of the two techniques was in the weight attached to specific elements. This was not unexpected, however, since they seek different types of trends. The results of the principal components analysis with its objective of efficient summarization are influenced to a greater extent by groups of highly correlated variables than by variables which are uncorrelated or only weakly correlated with other variables. The variables identified by discriminant analysis, on the other hand, are those variables which best distinguish among the sample groups and include those which are highly correlated with other variables as well as those which are not.

CONCLUSIONS

1. The species composition of the filamentous and epiphytic algae at the generating station and lakeshore sampling locations is similar to that observed in previous years of the study with the exception of an increased prominence of *Oedogonium* at the lakeshore sampling locations.

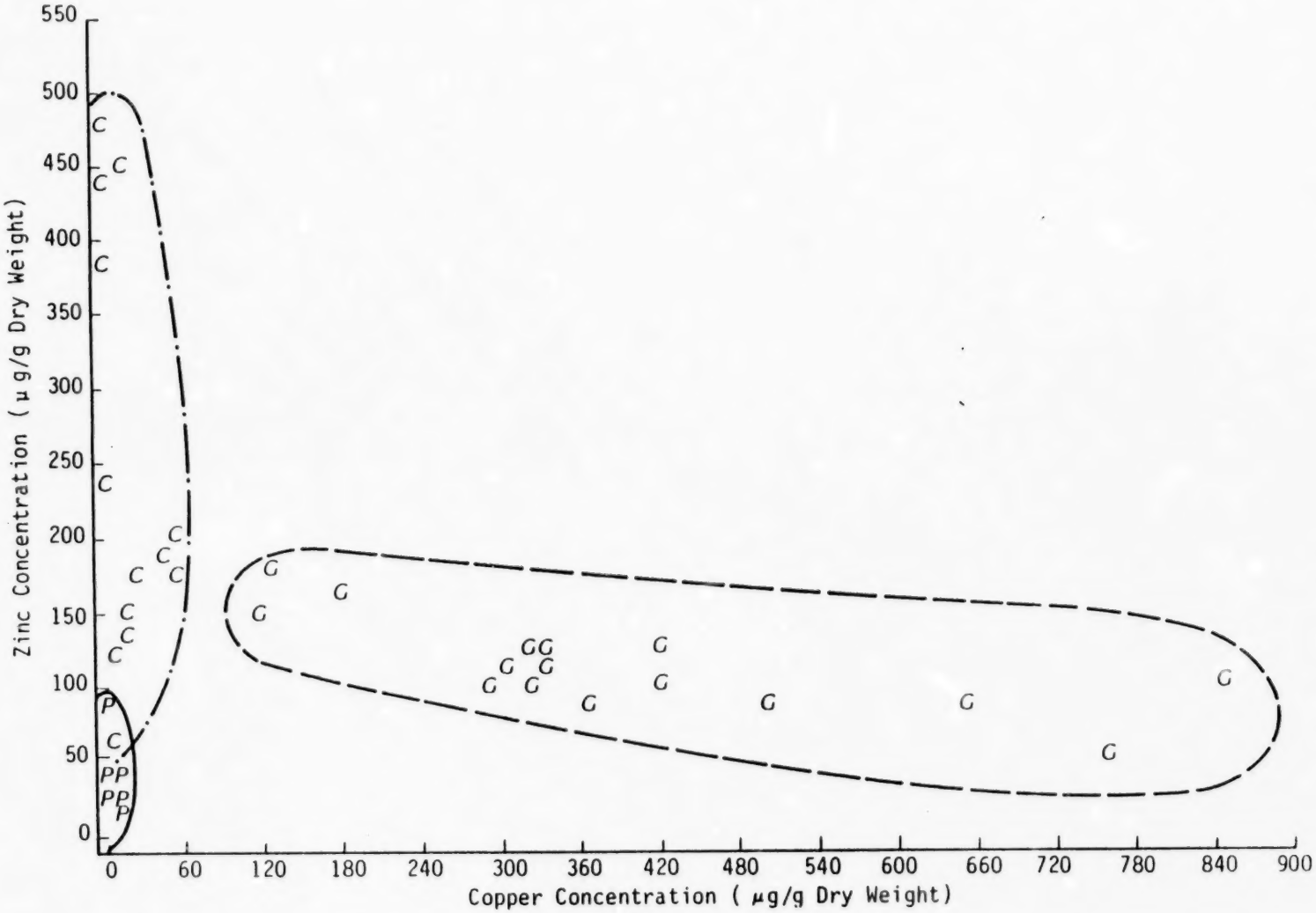


FIGURE 18
GRAPH OF THE COPPER AND ZINC CONCENTRATIONS IN THE ATTACHED ALGE FROM THE NANTICOKE STUDY AREA-1981 (G-GENERATING STATION, C-CENTRE CREEK, P-PEACOCK POINT)

TABLE 5

SUMMARY OF THE STEPWISE DISCRIMINANT ANALYSIS OF THE STANDARDIZED DATA

Step	Variable Entered	F Statistic	P > F
1	Cu	50.1	0.0001
2	Zn	21.9	0.0001
3	V	9.9	0.0003
4	P	7.7	0.0014

TABLE 6

COMPARISON OF THE NUMBER OF SAMPLES IN THE GROUPS DERIVED FROM THE DISCRIMINANT MODEL WITH ORIGINAL GROUPS

Allotted to/From	Centre Creek	GS5	Peacock Point
Centre Creek	12	0	3
GS5	0	17	0
Peacock Point	0	0	16

2. The attached algae at the generating station began growth earlier in the year than at the lakeshore sampling locations probably as a result of the ice free conditions existing in the discharge over the winter months. This trend has been observed previously.

3. The algae from Centre Creek (near Stelco) and the generating station generally contained higher concentrations of the following elements than the algae from Peacock Point: arsenic, aluminum, cobalt, zinc, phosphorus, iron, silicon, nickel, vanadium, mercury and chromium. Copper was found at higher concentrations in the algae from the generating station than in the algae from both Centre Creek and Peacock Point. Boron was higher in the controls than in the algae from Peacock Point and the generating station. The biomass at the lakeshore sampling locations was lower

in June and July than at the generating station largely as a result of severe storms which detached the algal filaments at the lakeshore, but not at the generating station.

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Biological Research Section

MKK:km

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APPENDIX 1

CHLOROPHYLL 'a' CONCENTRATIONS (mg chl'a'/g Carbon)
OF THE ATTACHED ALGAE AT NANTICOKE GS - 1981

Location	April	May	June	July	August	September	October
L_1	12.0 12.0		10.0 7.5 6.6	3.2		10.0	
L_4		7.8 4.4	7.1 8.2			5.0 5.3 4.7	
L_8			5.2	1.0 1.3 3.1	2.7	4.9	
GS_4		4.1	3.5 2.8 3.3	3.5 5.4 5.5	10.0 8.0 2.2	13.0 9.6 5.8	
GS_5	0.6 6.6 5.6	3.8 1.8	10.0			6.0	11.0

APPENDIX 3

PER CENT COMPOSITION OF ATTACHED ALGAE AND PRESENCE OF EPIPHYTIC ALGAE - MANITCOKE GS - 1981

	April									May										June										July										August										September										October									
	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7	L_1	L_2	L_3	L_4	L_7	L_8	GS_4	GS_5	GS_7
Attached Algae																																																																											
Bangia atropurpurea																																																																											
Cladophora glomerata	98						77	100	10	100	100	52	100	100	33	2	67	28	100	82	53	50	27	18			54	100	36	29	1	40	2		100	35	82	99	99	1	63		90	3	100	7	100	100	24 74	70	93	96	78	100	66	100	100	23 55	97	12 88	100	78		100
Cladophora sp																															10					64																																				
Lyngbya sp																														13																																								
Microspora sp																																																																							
Mougeotia sp												23				75					10	2	7	1	45	5	8			2	13		3	61						5																												
Oedogonium sp																				17	27	41	55	78					63	47	55	60	95	1				1		40	95	10					1	30	7	6			1			2	3			19		
Oscillatoria sp																																			1																																				
Phormidium sp																																								1																														
Spirogyra sp												3									9	3		2						1	1																																								
Stigeoclonium sp	2						10		50																3											1	18						38		30												13			1									
Ulothrix sp							13		40			23			67						1			2							20			36		1																																	
Ulothrix zonata																23	33	42		1			1		52	95	39																																														
Epiphytic Algae																																				+																																				
Calothrix sp																																					+	+	+																																
Cocconels sp												+			+				+	+	+	+	+	+			+	+	+	+	+	+			+	+	+	+																																
Cymbella sp											+	+	+	+	+			+		+	+	+	+	+			+	+	+	+	+	+					+																															
Gomphonema sp																																					+	+																																
Rhoicosphenia curvata	+						+	+	+	+	+		+					+		+	+	+	+	+			+	+	+		+				+	+	+																														
Synedra sp	+																					+																																														
Ulvaceae sp																																																																						

APPENDIX 3

ASH FREE DRY WEIGHTS (g/m^2) OF THE ATTACHED ALGAL SAMPLES
- NANTICOKE GS - 1981

	April	May	June	July	August	September	October
L_1	47.05	132.00	227.84	11.92	18.56	15.52	51.60
L_1	58.88	322.60	92.04	39.92	6.04	53.36	62.40
L_1	47.48	221.32	151.68	7.72	30.28	NS	19.24
L_2	0.0	197.32	3.48	7.04	46.88	97.92	132.20
L_2	0.0	134.60	18.28	9.60	74.04	NS	99.08
L_2	0.0	77.48	911.12	8.52	50.80	NS	15.16
L_3	0.0	67.04	0.96	3.08	72.60	82.00	83.84
L_3	0.0	95.16	10.08	5.52	187.28	86.04	144.76
L_3	0.0	38.44	25.40	1.80	168.36	86.20	11.44
L_4	0.0	304.64	15.92	0.92	6.40	7.92	32.48
L_4	0.0	353.20	10.52	0.60	10.40	22.00	6.16
L_4	0.0	433.88	1.84	12.56	7.88	15.64	37.88
L_7	0.0	191.72	0.52	11.08	0.40	14.24	31.40
L_7	0.0	161.92	1.08	3.28	0.52	44.04	48.08
L_7	0.0	155.48	0.64	6.60	0.44	81.48	15.08
L_8	0.0	15.12	4.32	7.08	47.56	139.32	NS
L_8	0.0	217.20	6.16	7.04	43.52	75.80	NS
L_8	0.0	14.60	8.60	10.32	16.72	49.84	NS
GS_4	4.16	32.88	17.20	33.24	6.96	41.08	20.72
GS_4	48.64	16.08	24.08	43.68	17.28	45.04	40.24
GS_4	33.24	50.36	14.48	31.80	6.24	45.52	46.64
GS_5	212.56	292.32	19.60	490.64	95.56	23.00	78.64
GS_5	122.32	112.92	89.60	102.52	102.08	140.88	100.40
GS_5	6915.70	19.84	37.68	401.88	120.36	62.92	36.56
GS_7	8.56	174.84	43.88	14.12	116.76	7.96	5.80
GS_7	10.28	80.04	4.72	45.60	147.16	93.80	95.12
GS_7	11.40	59.60	16.00	9.20	19.40	76.60	60.56

NS - sample not collected

APPENDIX 4

CONCENTRATION OF HEAVY METALS AND NUTRIENTS IN ATTACHED ALGAE, NANTICOKE GS - 1981

Concentrations are in ug/g dry weight of algae except for N and P (mg/g dry weight) and B and Si (% dry weight). NA = not analysed. * outlier omitted from statistical analyses.

Station	Month	Al	As	Be	Mg	N	Se	V	As	Cd	Cr	Hg	Pb	Si	Zn	B	Cu	Ni	P	S	Co
GS5	Apr	3 800	[illegible]	11 000	3 800	32.60	0.60	14.00	4.30	1.90	17.00	0.12	56.00	1.50	53.00	9.30	760.00	9.00	0.70	2.50	35 000
GS5	May	5 900	[illegible]	17 000	3 400	14.40	1.60	19.00	4.00	2.10	27.00	0.06	* 8.30*	3.00	100.00	1.7*	290.00	14.00	1.40	2.20	69 000
GS5	May	4 700	[illegible]	13 000	3 600	22.90	1.70	18.00	3.50	1.90	28.00	0.08	110.00	2.70	98.00	23.00	320.00	15.00	1.30	2.30	57 000
GS5	May	6 500	[illegible]	20 000	4 300	20.50	2.00	25.00	4.10	1.80	34.00	0.10	113.00	4.40	120.00	13.00	320.00	22.00	1.30	2.20	72 000
GS5	Jun	11 000	3.90	* 500*	8 300	21.00	<0.30	24.00	7.50	1.30	20.00	0.26	50.00	4.00	110.00	1.50	* 30.00*	17.00	1.20	2.40	60 000
GS5	Jun	10 000	3.30	6 200	6 800	25.00	<0.30	19.00	8.40	1.60	21.00	0.20	56.00	3.60	110.00	3.70	330.00	15.00	1.50	2.80	36 000
GS5	Jun	9 900	3.30	7 400	5 700	31.60	<0.30	19.00	7.50	1.50	22.00	0.18	76.00	3.00	110.00	19.00	300.00	15.00	2.50	2.70	34 000
GS5	Jul	12 000	5.30	12 000	6 900	19.00	0.80	27.00	4.20	<0.30	17.00	0.09	49.00	4.00	160.00	160.00	180.00	13.00	1.30	2.30	56 000
GS5	Jul	12 000	4.90	11 000	6 800	18.70	0.70	30.00	4.50	<0.30	17.00	0.07	53.00	4.20	170.00	150.00	130.00	15.00	1.30	1.80	75 000
GS5	Jul	9 100	4.10	8 900	6 100	17.40	0.80	28.00	3.50	<0.30	15.00	0.08	59.00	3.70	150.00	150.00	110.00	13.00	1.10	1.90	77 000
GS5	Aug	7 460	4.50	8 700	6 540	24.40	<0.30	15.00	4.40	0.89	14.00	0.16	13.00	4.50	120.00	140.00	330.00	13.00	1.60	4.40	53 400
GS5	Aug	8 100	5.50	10 000	7 160	33.50	<0.30	16.00	4.40	1.00	15.00	0.01	17.00	4.40	130.00	140.00	420.00	24.00	1.70	4.40	54 100
GS5	Sep	4 000	3.20	6 500	4 700	42.50	<0.30	9.00	8.20	0.67	8.40	0.09	5.40	3.30	99.00	180.00	420.00	9.30	3.50	2.30	30 000
GS5	Sep	3 500	2.90	5 700	4 200	21.40	0.30	8.00	7.10	0.60	7.60	0.12	4.80	3.10	89.00	190.00	500.00	7.20	1.50	2.20	24 000
GS5	Sep	3 800	3.30	6 300	4 600	26.80	0.50	8.80	7.80	0.62	8.20	0.15	5.10	3.10	94.00	180.00	850.00	8.60	1.80	2.10	29 000
GS5	Oct	3 300	2.80	5 200	4 400	54.50	1.03	7.70	17.40	0.90	7.30	0.03	5.10	4.00	88.00	250.00	370.00	7.00	4.10	2.49	27 000
GS5	Oct	3 400	3.20	5 800	4 500	60.00	0.83	8.10	15.95	1.10	7.60	0.08	5.20	3.80	90.00	260.00	650.00	7.00	5.30	2.62	22 000
GS5	Oct	3 800	3.20	6 100	4 800	64.00	1.02	8.70	15.95	0.89	8.20	0.18	6.00	4.80	100.00	240.00	420.00	8.00	6.00	2.29	29 000
L1	May	11 000	6.10	21 000	5 700	29.60	1.10	* 3.90*	7.40	1.60	36.00	0.16	180.00	NA	390.00	8.90	<0.41	18.00	2.20	NA	51 000
L1	May	13 000	6.50	24 000	6 400	26.00	1.10	40.00	6.50	1.90	39.00	0.17	190.00	6.20	440.00	6.40	<0.45	20.00	2.20	1.40	64 000
L1	May	12 000	5.30	24 000	6 400	28.70	1.20	39.00	7.20	1.70	41.00	0.13	200.00	5.30	480.00	3.60	<0.50	16.00	2.70	1.60	56 000
L1	Jun	2 500	0.99	2 200	3 200	39.80	<0.30	6.40	10.40	0.82	15.00	0.13	17.00	1.30	64.00	6.50	5.70	4.00	3.20	3.50	17 000
L1	Jun	3 200	1.70	1 600	3 100	33.20	<0.30	6.50	9.00	0.63	14.00	0.10	13.00	1.60	66.00	7.50	5.40	4.70	2.60	3.30	16 000
L1	Jun	2 100	<0.96	1 700	3 100	39.10	<0.30	6.70	9.10	0.75	14.00	0.14	22.00	1.00	57.00	11.00	4.90	3.60	3.20	3.40	17 000
L1	Jul	8 400	3.40	8 300	4 900	23.20	1.20	17.00	9.00	2.70	18.00	0.17	130.00	2.30	450.00	130.00	15.00	13.00	1.10	3.30	28 000
L1	Jul	16 000*	8.30	15 000	6 800	19.10	2.90	37.00	7.20	2.70	18.00	0.24	130.00	7.60	450.00	150.00	15.00	13.00	1.90	1.10	51 000
L1	Jul	2 100	<2.00	2 400	2 900	23.20	1.00	<7.00	8.20	0.94	8.10	0.08	110.00	1.20	240.00	150.00	8.10	4.70	1.00	3.10	17 000
L1	Aug	11 600	7.80	13 100	8 260	21.40	1.20	19.00	4.80	0.89	20.00	0.05	31.00	8.70	200.00	81.00	54.00	18.00	3.70	0.60	64 400
L1	Aug	13 700	10.00	15 300	10 400	13.20	0.90	21.00	4.20	1.00	23.00	0.05	29.00	10.10	190.00	60.00	44.00	18.00	3.00	0.60	65 700
L1	Aug	11 100	7.20	12 500	7 920	18.10	0.90	17.00	4.40	0.76	20.00	0.05	29.00	9.60	170.00	95.00	50.00	18.00	2.60	0.60	59 900
L1	Sep	4 080	4.00	6 580	4 460	30.00	0.50	9.00	3.60	0.44	13.00	0.06	16.00	3.50	140.00	98.00	13.00	7.40	3.20	2.10	28 700
L1	Sep	1 800	1.90	3 700	3 500	42.50	0.40	4.50	4.20	0.52	8.20	0.10	14.00	1.70	130.00	130.00	8.20	3.30	8.50	2.70	16 000
L1	Sep	6 800	7.00	12 000	5 000	30.50	0.40	18.00	4.80	0.36	14.00	0.06	18.00	9.00	150.00	66.00	14.00	10.00	4.20	0.70	42 000
L1	Oct	1 600	2.20	4 000	2 900	45.50	0.43	5.60	73.94	0.48	7.10	0.13	21.00	1.99	170.00	200.00	24.00	3.60	2.80	2.54	21 000
L8	Apr	7 600	5.30	13 000	5 000	14.80	1.00	29.00	3.00	0.93	21.00	0.05	73.00	3.40	82.00	14.00	<0.41	13.00	1.10	1.60	150 000
L8	May	2 700	0.84	3 400	3 400	22.20	0.30	9.30	1.00	1.00	11.00	<0.01	54.00	1.00	25.00	25.00	<0.42	4.40	0.80	2.80	39 000
L8	May	2 400	<0.87	2 800	3 100	17.80	0.30	9.60	1.00	0.74	9.40	0.01	20.00	1.20	23.60	2.90*	1.10	3.80	0.70	3.10	35 000
L8	May	3 800	2.00	5 400	4 200	17.10	0.30	15.00	1.50	0.34	12.00	0.01	44.00	1.70	31.00	16.00	<0.50	4.50	0.70	3.30	48 000
L8	Jun	2 800	1.90	3 900	4 000	20.00	<0.30	1.90	2.10	0.41	10.00	0.05	92.00	0.90	63.00	8.90	3.90	7.00	1.30	2.50	100 000
L8	Jun	3 100	<0.99	3 600	3 800	26.50	<0.30	8.40	1.80	<0.30	9.60	0.04	76.00	1.10	34.00	13.00	<0.50	6.10	1.70	2.60	85 000
L8	Jun	2 800	[illegible]	3 000	3 700	29.60	<0.30	8.80	2.00	0.95	10.00	0.02	56.00	0.70	29.00	14.00	2.00	6.80	1.70	2.60	91 000
L8	Jul	3 000	[illegible]	2 900	3 100	20.00	0.80	7.80	2.20	<0.30	7.40	0.02	74.00	1.20	26.00	200.00	8.40	8.40	0.80	3.00	56 000
L8	Jul	2 500	[illegible]	2 800	3 200	18.80	0.90	6.80	1.90	4.30	11.00	0.02	73.00	1.20	29.00	700.00	11.00	7.40	0.80	2.80	71 000
L8	Jul	2 500	[illegible]	2 300	3 000	21.00	0.80	8.20	2.40	2.60	11.00	0.02	71.00	1.00	27.00	170.00	7.60	7.80	0.80	2.60	56 000
L8	Sep	1 900	[illegible]	3 100	3 100	21.50	0.30	4.90	4.50	0.81	4.70	0.02	<5.00	2.00	20.00	280.00	9.90	8.10	0.70	2.20	29 000
L8	Sep	1 600	[illegible]	2 900	2 300	17.60	<0.30	4.40	4.50	1.20	3.90	0.02	3.20	1.60	23.00	250.00	8.10	3.90	0.60	2.00	18 000
L8	Sep	1 700	[illegible]	2 900	3 200	21.90	<0.30	4.60	4.10	0.96	4.30	0.02	<5.00	1.90	18.00	280.00	9.50	3.90	0.70	2.10	27 000
L8	Oct	[illegible]	[illegible]	1 600	3 400	23.80	0.24	2.70	8.00	0.55	3.40	<0.01	2.50	1.00	17.00	240.00	7.10	2.60	1.60	2.23	31 000
L8	Oct	940	[illegible]	1 600	3 400	33.60	0.28	2.90	12.20	0.80	3.90	<0.01	4.40	1.10	28.00	290.00	9.00	3.40	3.40	2.85	37 000
L8	Oct	950	[illegible]	2 000	3 300	17.50	0.24	3.50	6.00	0.43	3.40	<0.01	3.60	1.30	12.00	190.00	7.80	2.70	0.90	2.39	33 000
L4	May	13 000	6.40	15 000	10 000	11.70	0.50	3.40	2.50	<0.28	25.00	0.09	81.00	5.50	85.00	35.00	<0.47	16.00	0.90	1.90	100 000
L4	May	13 000	6.20	14 000	9 700	10.40	0.90	35.00	2.60	<0.28	23.00	0.08	72.00	5.30	85.00	20.00	<0.47	15.00	0.80	1.70	95 000
L4	May	13 000	6.80	14 000	9 100	11.80	0.80	3.20	2.50	<0.29	22.00	0.05	85.00	4.50	79.00	33.00	<0.48	14.00	0.80	2.20	93 000
L4	Jun	9 000	4.50	11 000	6 900	15.50	<0.30	21.00	3.50	1.10	18.00	0.13	94.00	3.20	88.00	29.00	0.64	17.00	0.80	2.20	78 000
L4	Jun	7 500	4.40	9 700	6 000	16.00	<0.30	19.00	3.10	0.82	18.00	0.06	56.00	3.40	83.00	31.00	1.70	17.00	0.80	2.20	70 000
L4	Jun	8 300	3.80	7 900	6 100	16.40	<0.30	18.00	3.40	0.95	16.00	0.03	69.00	3.20	80.00	22.00	4.70	17.00	0.70	2.20	68 000
GS4	Apr	5 100	1.90	13 000	4 000	25.60	1.00	19.00	3.50	2.30	23.00	0.03	77.00	3.10	81.00	10.00	260.00	13.00	1.70	2.20	44 000
GS4	May	1 800	[illegible]	5 800	6 100	35.70	0.60	5.40	2.00	2.50	20.00	0.24	140.00	0.80	110.00	29.00	260.00	7.50	1.80	3.20	35 000
GS4	May	2 200	[illegible]	6 000	5 200	42.30	0.60	7.00	2.10	2.30	21.00	0.06	110.00	0.90	100.00	4.80	170.00	7.40	2.00	2.60	34 000
GS4	Jul	11 000	[illegible]	12 000	7 400	15.50	0.80	31.00	4.60	<0.30	18.00	0.10	36.00	4.10	140.00	35.00	95.00	11.00	1.30	1.00	78 000
GS4	Jul	11 000	[illegible]	12 000	8 000	11.60	0.80	31.00	4.90	<0.30	19.00	0.14	37.00	5.10	140.00	27.00	75.00	12.00	1.00	0.50	83 000
GS4	Jul	12 000	[illegible]	13 000	8 600	11.40	0.80	30.00	5.20	<0.30	19.00	0.09	43.00	5.10	140.00	36.00	76.00	13.00	1.20	0.90	70 000
GS4	Sep	10 000	[illegible]	16 000	11 000	9.30	1.00	22.00	7.40	0.4	16.00	0.70	12.00	9.40	140.00	46.00	160.00	26.00	1.30	0.20	93 000

NOTE [illegible]

* [illegible] In subsequent investigation these reported values were found to be 1/10 of the measured concentrations.

POOR

QUALITY

ORIGINAL